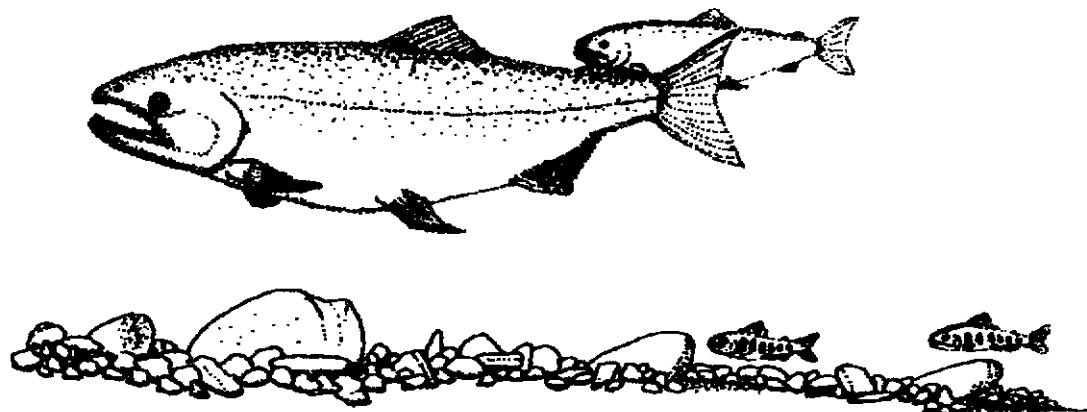


**U.S. FISH AND WILDLIFE SERVICE**

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**FISH HABITAT ANALYSIS FOR THE DUNGENESS RIVER  
USING THE INSTREAM FLOW INCREMENTAL METHODOLOGY**



**WESTERN WASHINGTON FISHERY RESOURCE OFFICE**

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**OLYMPIA, WASHINGTON**

**JULY 1991**

**Fish Habitat Analysis for the Dungeness River  
Using the Instream Flow Incremental Methodology**

by

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## ABSTRACT

An instream flow study of discharges required for fish use was performed by the Western Washington Fishery Resource Office, U.S. Fish and Wildlife Service (FWS), Olympia, Washington, and cooperating agencies of Washington State during 1988 and 1989, in the lower Dungeness River, Washington. We performed the study as part of a comprehensive effort to restore degraded runs of anadromous fish, particularly spring chinook and pink salmon. We used the FWS Instream Flow Incremental Methodology (IFIM) and associated software to develop predictions of weighted useable area (WUA) per 1000 ft of stream for study sites located at river miles (RM) 2.3 and 4.2. The two study sites were selected to represent instream habitat found in river reaches from RM 1.8 to 2.5 and 3.3 to 6.4, respectively. Upstream of the represented reaches are five points of irrigation withdrawal that remove varying amounts of water throughout the year. The principal objective of the study was to determine discharge vs. anadromous salmonid habitat relationships for the lower Dungeness River.

Using the IFG4 program to create hydraulic models from data collected at the study sites, we developed 10 models for the upper site and four models for the lower site. We ran all models on single sets of velocities from a series of transects. We obtained WUA predictions vs. a range of discharges from the HABSTAT program. WUA predictions were obtained for steelhead spawning, juvenile and adult, Dolly Varden juvenile, coho spawning and juvenile, chinook juvenile, spring chinook spawning and adult, and pink spawning.

#### **ACKNOWLEDGEMENTS**

This study was performed in cooperation with the Washington Departments of Ecology, Fisheries, and Wildlife. Steve Hirshey and Brad Caldwell of WDE contributed greatly to both the successful collection of field data and the determination of appropriate strategy for computer analysis of the data. Hal Beecher (WDW) helped plan and performed much of the work to collect habitat criteria verification data and to develop that data. Ken Bruya (WDF) and John Carleton (WDW) also assisted in collecting the habitat criteria verification data. Dell Simmons (FWS, Vancouver, WA) provided information essential to our successful use of the PHABSIM computer software. Also assisting in the collection of hydraulic data were Dick Walker (WDE) and members of the Washington Conservation Corps. Bernaht Wampler (FWS Volunteer) assisted in the collection of all elevation surveying data. Brian Winter (NMFS, Seattle, WA) assisted with review of the draft report. Finally, we are grateful to WDE for making available a boat and associated flow measurement equipment.

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## INTRODUCTION

Native runs of anadromous salmonids that rely on habitat found in the lower Dungeness River, and particularly fish present during summer months, have been degraded by the impact of annual irrigation withdrawals (Williams et al. 1975; Anon. 1988). Water withdrawals, excess gravel from high flow bedload movements through the lower river, and periods of low seasonal runoff have combined to prevent free upstream migration of returned adults in some years. Area of suitable habitat for spawning and rearing during the period of withdrawal are also reduced. These reductions are thought to be major contributing factors in the decline of the spring chinook and pink salmon runs.

The Dungeness River Management Team (DRMT) was formed in 1987 to bring together land use managers, homeowners, farmers, fishery managers and forestry representatives to deal with habitat management issues in the Dungeness watershed. The DRMT recognized the need to describe the relationship between river flow and habitat for anadromous fish. This information could then be used to determine how much additional habitat could be gained from reductions in withdrawals.

The U.S. Fish and Wildlife Service (FWS) proposed an instream flow study to evaluate the availability of suitable habitat area for fish relative to the flows present in the reach from river mile (RM) 1.8 to 11.0. The DRMT agreed that the study should proceed. We performed the instream flow study during 1988 and 1989 with guidance from an interagency technical team. This report describes the study and discusses some analyses of the results.

## STUDY AREA

The Dungeness River is fed primarily by snow melt, but summer rains also contribute to alleviate low summer flows. Early summer temperatures affect rate of snow melt and thus, the natural reserve available for late summer. There are three streams that contribute some inflow within the study reach (RM 1.8 to 11.0) and five irrigation diversions between RM 6.8 and 11.0 (Figure 1). Part of the diverted flow returns to the river as surface flow (Figure 2), part feeds independent streams either via surface or seepage, and part enters directly into tidewater. Most of the return surface water comes from Clallam Ditch via Matriotti Creek.

Upstream of the USGS stream gage (RM 11.4), seasonal low flows occur in September and October, with 90% exceedence levels (i.e., flows exceeded 90% of the time according to past data) averaging 118 and 103 cfs, respectively (Figure 3). For any month of the year, diversion takes the largest relative percentage of instream flow in September (Figure 4). As a result, river flow below the diversions tends to reach its lowest level during the period late August to early September (Figure 5). For the years that we have data, there were unusually low river flows in September and October. After mid-September, irrigation usually ended, but reduced rates of diversion continued.

The effect of withdrawal is magnified by seepage into the water table. Measurements have shown that approximately 10 cfs is lost to intergravel seepage from the river channel between the diversion withdrawals and the vicinity of Woodcock Bridge (Appendix A, Table 3).

#### METHODS

We used the Instream Flow Incremental Methodology (IFIM) to model instream habitat availability to anadromous fish species for selected life stages in the Dungeness River, Washington. The IFIM was developed by the Cooperative Instream Flow Service Group, today identified as the Aquatic Branch, Aquatic Systems Modeling Section, National Ecology Research Center, Fort Collins, Colorado. The IFIM incorporates field measurements, computer generated hydraulic simulation, and fish habitat criteria curves for input to the HABTAT computer program (Table 1). HABTAT produces predictions of weighted useable area (WUA) of habitat per 1000 ft length of stream. WUA is the total surface area having a specific combination of hydraulic conditions, multiplied by the respective weighting factor for those conditions (Milhous et al. 1984). Measurements made along transects across a stream are used to model cells containing specific combinations of hydraulic conditions. The weighting factor is derived from habitat criteria curves.

#### Hydraulic Model Data Collection

The initial step in applying the IFIM was to identify reaches of the river that contained characteristics distinctly different from one another, and then to select representative study sites within those reaches. On April 12, 1988, the Dungeness instream flow technical group, consisting of instream flow specialists from the Washington Departments of Fisheries (WDF) and Ecology (WDE), and FWS, decided that there were two distinguishable reaches, the lower reach extending from RM 1.8 to 2.5 and the upper reach extending from RM 3.3 to 11.0. The group concluded that the upper site should be located below RM 6.4 to avoid complications for modelling found upstream, specifically, the numerous points of water withdrawal, islands, and side channels.

The technical group met at the lower river on April 25, 1988, to walk the river from RM 6.4 to 1.8 to confirm the distinguishing characteristics of the two reaches and to select locations for study sites within each reach. The group determined that the upper reach was characterized by moderate stream bed gradient and frequent channel braiding while the lower reach was characterized by lower gradient and a single channel. Following the walk, the group determined that the upper and lower reaches should be represented by study sites at RM 4.2 and 2.3, respectively. Later that month, we selected and marked eight transects within each of the two study sites to represent the habitat and hydraulic variations present (Figures 6 and 7).

Following guidance established by WDW, WDF, AND WDE, we planned to use the three-flow IFIM, referred to as IFG4 (Table 1). The purpose of IFG4 is to

develop the depth and velocity data required by the HABTAT program. The IFG4 model was designed to simulate cross-sectional velocities at a number of flows (discharges) and water surface elevations (WSEL). The IFG4 is based on the assumption that WSEL and velocity exhibit a log-log linear relationship to discharge (Milhous et al. 1984). The velocity set(s) must be measured within the range of discharges of interest.

Based on past U. S. Geological Survey (USGS) flow records (Figure 3), we developed a set of flow exceedence curves for the Dungeness River. From those curves we determined the approximate dates on which to collect data. We planned to sequence data collections from highest flow to lowest flow to reduce the risk of change in the bed profile along transects. The focus of our concern was the period of relative low flow as it coincides with presence of anadromous salmonids in the lower river (Figures 4 and 8).

During June, 1988, we collected high flow data sets at the upper and lower sites (Table 2). We made depth and velocity measurements at points referred to as verticals along a beaded cable positioned and held taut at each transect. Wherever possible, we made measurements while wading, using a Swoffer instantaneous flow meter mounted on a top-setting wading rod. Where necessary, we made other measurements from a boat equipped with the meter suspended by cable and reel from a boom and cross-piece. Before and after each transect measurement we read the water level on a temporary WSEL gage to assure that any change in WSEL did not exceed 1/8 in. During subsequent data collections we also visually assessed dominant and subdominant substrate types along transects, using the three-digit code described by Young (1983).

Transect WSEL and profiles beyond the water's edge were measured with an automatic level mounted on a tripod while reading a stadia rod. WSEL data were related to a permanent benchmark that we established above the high flow level of the river. After we measured WSEL for each data collection, we always surveyed back to the benchmark to assure data accuracy. All data were recorded in notebooks and checked for accuracy and completion prior to leaving the site.

We collected data at the lower site, containing a single channel, with relatively little difficulty. The high flow measurement required use of the boat and associated equipment. However, the braided channel of the upper site presented a more complex task (Figure 6). Based on the original assumption that we would create a single hydraulic model, most of the transects had to cross multiple channels at the same WSEL. This made surveying considerably more difficult at transects 1 and 4-8. At low flow, the right side channel at transect 1, the right side channel at transects 3 to 6, and the "middle" channel at transects 7 and 8 contained no flow. All scheduled flow measurements were accomplished by September, 1988 (Table 3).

Depths and velocities were not measured at the same verticals during the second flow measurement that had been used during the first measurement. This meant that separate hydraulic models had to be developed for high and medium/low data sets.

Once obtained, WSEL across most transects at the upper site varied so much that all channels on a transect could not be modelled together satisfactorily. Thus, multiple channels had to be modelled individually. Moreover, it was not recommended that hydraulic models consist of only two velocity sets because prediction reliability is reduced when based on regressions from only two data points. Instead, a series of one-flow IFG4 models, i.e., models using only one set of calibration velocities, were recommended as being about as reliable for predictions as 3-flow models (R. Milhous, National Ecology Research Center, pers. comm.).

WDW requested additional modelling in the upper site to better represent habitat preference of rearing juveniles and holding adults during the period of lowest flow in late summer. We collected one set of velocity measurements on two transects specifically located to intersect deep pools in the main channel of the upper site. As a result, hydraulic data for two transects were added to the low flow range model for the main channel.

With assistance from WDW, we assessed the approximate proportions of major stream habitat types, i.e., pool, riffle, and run, in the upper river reach. Our purpose was to use these relative percentages to guide adjustment of weighting given transects in the upper site, according to their respective habitat type representation. We rafted from RM 6.0 to 4.0, recording habitat types and assigning approximate stream distances. Later, we totalled distances by habitat type and determined the percentage of each habitat type. We concluded that this process was unnecessary for the lower reach because the transects in the lower site were assumed to adequately represent habitat type proportionality.

#### Hydraulic Models

Use of the IFG4 program to generate hydraulic models required that data for a site be assembled in a very specific format. Using IFG4IN (Table 1), we input the data for calibration discharges (i.e., the actual discharges measured at the site), measurement point distances and elevations along each transect, velocities measured at verticals on transects, WSEL measurements, and coded substrate evaluations at verticals. The product obtained from correctly assembling a data set in IFG4IN is the data file. We also used the program CKI4 (Table 1) to locate errors in the file format.

We constructed 10 data files for the upper site and four for the lower site (Table 3, Appendix B). For the main channel in the upper site, we constructed two different models from the 326 cfs intermediate velocity set. With the objective of using the model that best predicted WUA for a specific flow range, we compared the output from these models with the output from the respective low velocity set or the respective high velocity set. Similarly, for the upper site right channel T 1 (transect one) and left channel T 5-8, we constructed, ran, and compared output from two models using different velocity sets. We eliminated models for the low velocity sets from right channel T 3-6 and middle channel T 7 and 8 after concluding that those calibration (measured) discharges caused incorrect WSEL predictions at high flows (B. Caldwell, WDE, pers. comm.).

After comparing habitat type percentages found in the upper reach to the proportions of those habitat types represented by transects in the upper site (main channel), we increased the weighting of transects 5 and 7. Transect weighting should not be confused with the weighting factor derived from habitat criteria curves. This transect weighting expanded representation of pool habitat. We weighted all transects in the lower site equally.

For the lower site, we again constructed two different models from the 351.5 cfs intermediate velocity set (Table 3). We then compared that output to the output from the respective low and high velocity set models.

Once constructed, we ran finished data files on the IFG4 program. The output files produced by IFG4 consist of (1) an output file that displays results from selected input/output options and (2) two files formatted to input the calibrated hydraulic model to HABTAT. The output file contains information such as velocity adjustment factors, computed Manning's n values and computed cell velocities for each transect, and warning notes or messages that indicate how well the model calibrated. When information in the output file indicated that further adjustments were required in the data file, we edited the data file accordingly. With few exceptions, we adhered to guidance offered by WDE regarding limits in making modifications of the data file (B. Caldwell, pers. comm.). Depending on the physical characteristics measured at a transect, the calibration process yielded output that varied from acceptable on the first calibration run through IFG4 to acceptable after several trial and error runs following minor adjustments in either Manning's n values or cell velocities.

#### Fish Habitat Criteria Curves

The use of habitat criteria curves is based on the assumption that individuals of a species select and utilize stream locations that contain the depth, velocity, substrate and cover characteristics they favor most, due to existing conditions, and that they will utilize locations less frequently as a characteristic becomes less favored. Habitat criteria curves most commonly used are two dimensional and represent the range of fish preference as weighting, ranging from 0.00 to 1.00 (Bovee and Cochraner 1977). Washington State agencies recommend that criteria curves be developed from data collected in the stream where an IFIM study occurs. If this is not possible, curve applicability should be verified by making observations in the study stream (H. Beecher, WDW, pers. comm.).

The Dungeness technical group determined that we should employ the habitat criteria curves recommended by WDW, WDF and WDE. Those agencies, as members of the technical group, required that we also perform a verification study of the depth and velocity curves for rearing juveniles.

Snorkel crews collected preference curve verification data in the upper site during September, 1988, and July, 1989 (Table 2). Crews observed fish and then marked, by species, locations where individual salmonids occupied a focal point of territory. Later in the same day, they measured water depth and mean column velocity at each location. From these data we constructed histograms of fish frequency distribution for depth and velocity. We then used depth and

velocity distribution matrices generated from the IFIM hydraulic models of the upper site to adjust the histograms to represent fish preference (Beecher 1990). We used those histograms (preference curves) to determine the most suitable habitat preference curves. Further details of this procedure are presented in Appendix C.

We assembled a total of 10 habitat criteria curve sets, including the new preference curves, to run with HABTAT to produce predictions of WUA over a selected range of discharges (Figures 9 through 18).

#### Habitat Models

We input each hydraulic data file and the habitat criteria curves to the HABTAT program to obtain predictions of WUA for each of the 10 criteria curve sets. We then created spreadsheet graphs of WUA vs. discharge for the paired high and low models and for the individual models (right channel, T 3-6, and middle channel, T 7 and 8). Based on review of the paired graphs and procedural recommendations of WDE (B. Caldwell, pers. comm.), we selected the WUA vs. discharge coordinates that would most reliably predict habitat over the respective range of modelled discharges. We then joined the selected WUA vs. discharge coordinates to cover the entire range of flows to be modelled in a single data set. Predictions for the individual models (unpaired) were directly useable.

For the data from the upper site, still separated into different channels, we constructed plots of main channel vs. side channel discharges measured on the same day. From these plotted lines we then determined, either directly or by interpolation, the correct distribution for combination of side channel WUA predictions with main channel WUA predictions. Finally, we created graphs of the combined range of WUA vs. discharge coordinates for each habitat criteria curve, for both the upper and lower sites.

#### RESULTS

We ran the data files (Appendix B) on the IFG4 program to obtain respective hydraulic models as output. Details of the hydraulic model calibrations, including changes in either cell velocities or Manning's N values and the velocity adjustment factors, are listed in Table 4.

Output, in the form of a matrix of predicted WUA vs. a selected range of discharges, was obtained by running HABTAT for each calibrated hydraulic model. Based on those predicted values, we assembled the final WUA vs. discharge values for the combined models and range of discharges for the upper and lower study sites (Tables 5 and 6).

Curves of the WUA vs. discharge predictions were developed (Figures 19 to 22). This format facilitates comparison of WUA availability to actual discharges typically present in the stream at a given time and presence or absence of a species and its stage.

## DISCUSSION

We used the HABTAT program to model WUA for the range of flows that can occur in a typical flow year in the lower Dungeness River, including those that occur during the period of summer low flow. Of principal concern to managers of anadromous fisheries are the modelled WUA predictions for those species and life stages present during the low flow months, from August through October (Figures 4 and 8, Tables 5 and 6). Those species and life stages include juvenile Dolly Varden, steelhead, and coho and chinook salmon, adult migrating/holding spring chinook salmon, and spawning spring chinook and pink salmon.

Fishery managers may conclude that higher priority for restoration must be assigned to the needs of selected species and life stages. The FWS has a mandate to restore nationally significant, interjurisdictional species. Because spring chinook and pink salmon populations are most severely depressed, we would assign them the highest priority.

Adult spring chinook begin migrating into the river in May, if not earlier, and seek out safe locations to rest and hide until they are ready to spawn, beginning in early August (Figure 8). During this period they are especially vulnerable to various forms of predation. This vulnerability is proportionally worsened as available pools lose depth when river flows decline. It is evident that the diminished rate of flow remaining in the river in August and September reduces the availability of useable holding habitat for adult spring chinook (Figure 4, Tables 5 and 6). Also, as rate of flow is artificially lowered during August and September, the potential for development of barriers to upstream passage caused by shallow riffles is increased. Such barriers potentially prevent adults from reaching preferred spawning habitat. Pink salmon also attempt to migrate to spawning habitat in the river during these months and face the same potential barriers and limitations.

The WUA predictions presented in this report provide a means for managers to evaluate the potential gains and losses that may result from specific discharges through the upper and lower study reaches. We are hopeful that review and interpretation of this information will stimulate new action leading to increased suitable habitat for anadromous salmonids.

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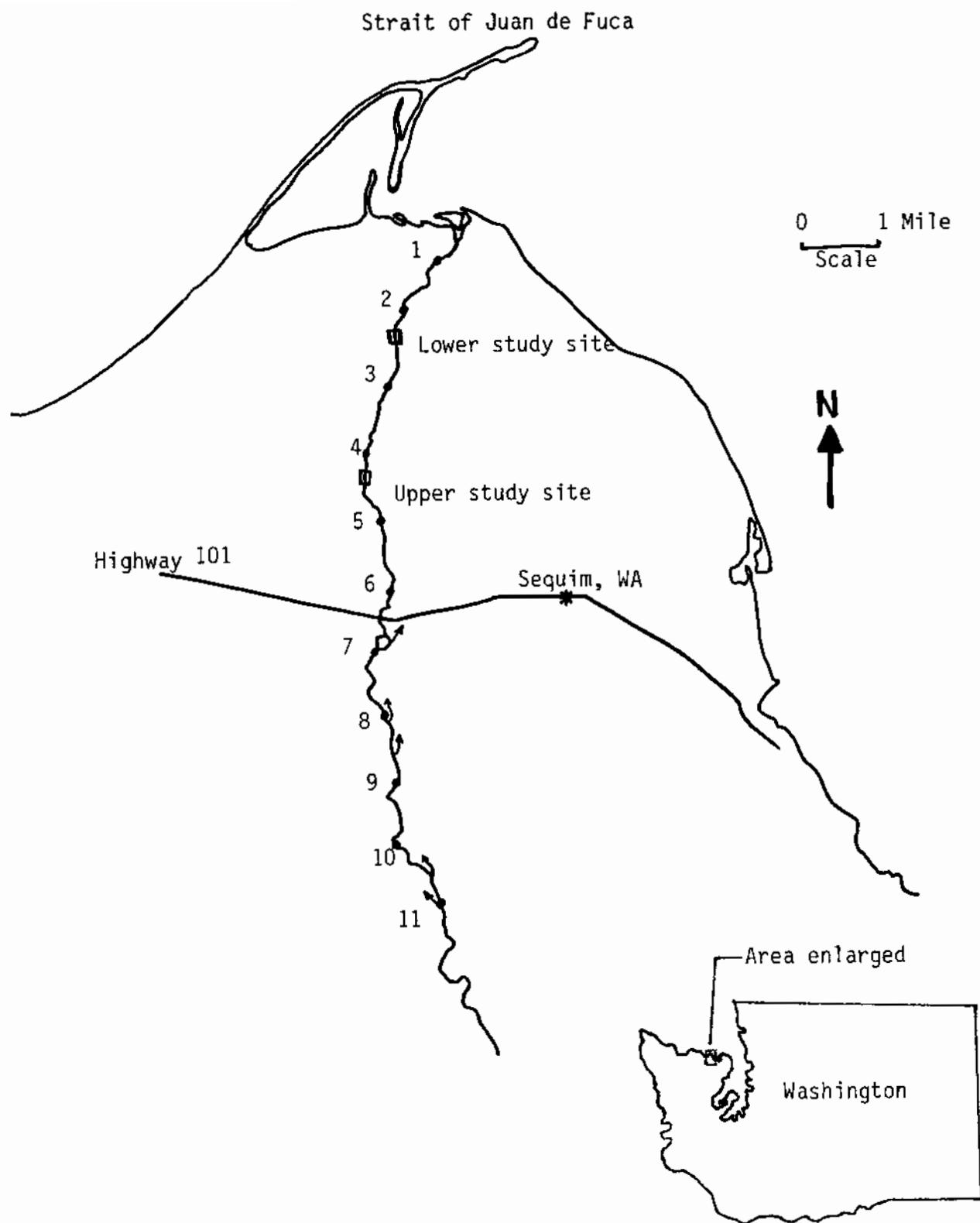


Figure 1. Lower Dungeness River, showing river miles (numbered) and study sites (boxes). Points of irrigation withdrawal are indicated by arrows leaving the river.

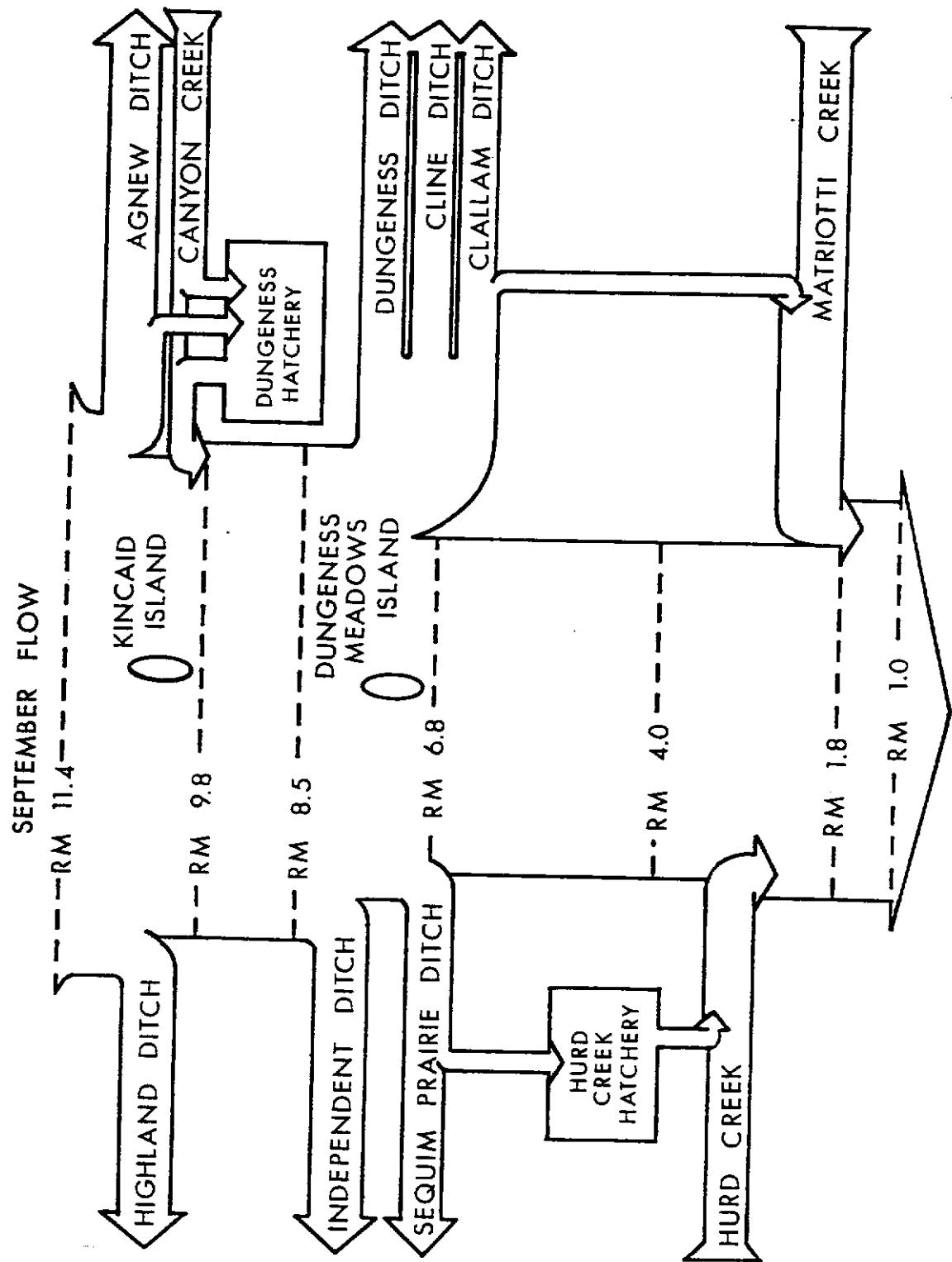


Figure 2. Dungeness River reaches affected by irrigation withdrawal. Vertical scale represents approximate river mile. Arrow width represents relative amount of typical summer flow.

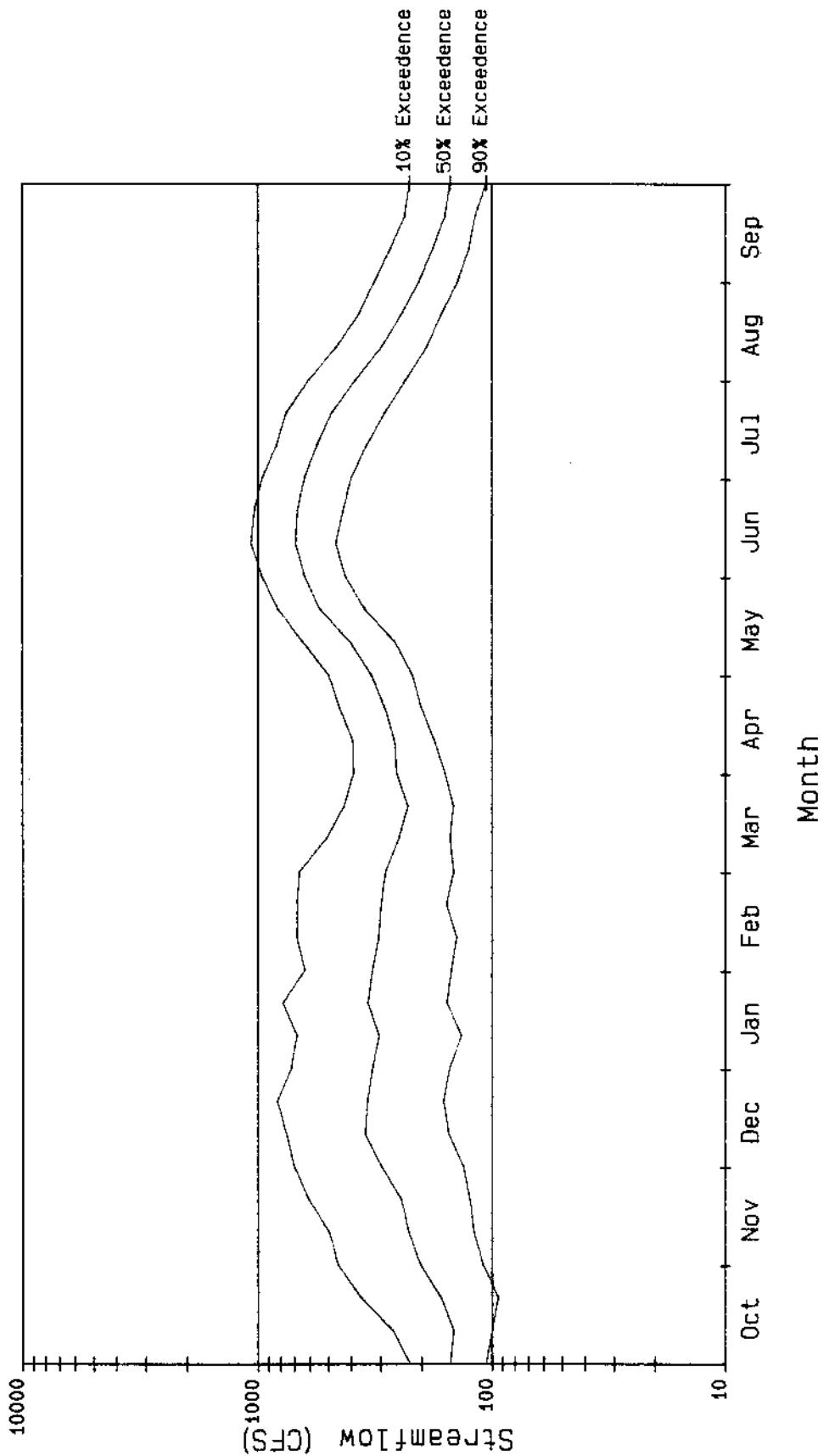


Figure 3. Dungeness River flow exceedence curves, for the period 1923 to 1989.  
From U.S. Geological Survey, gaging station 12048000, Sequim, WA.

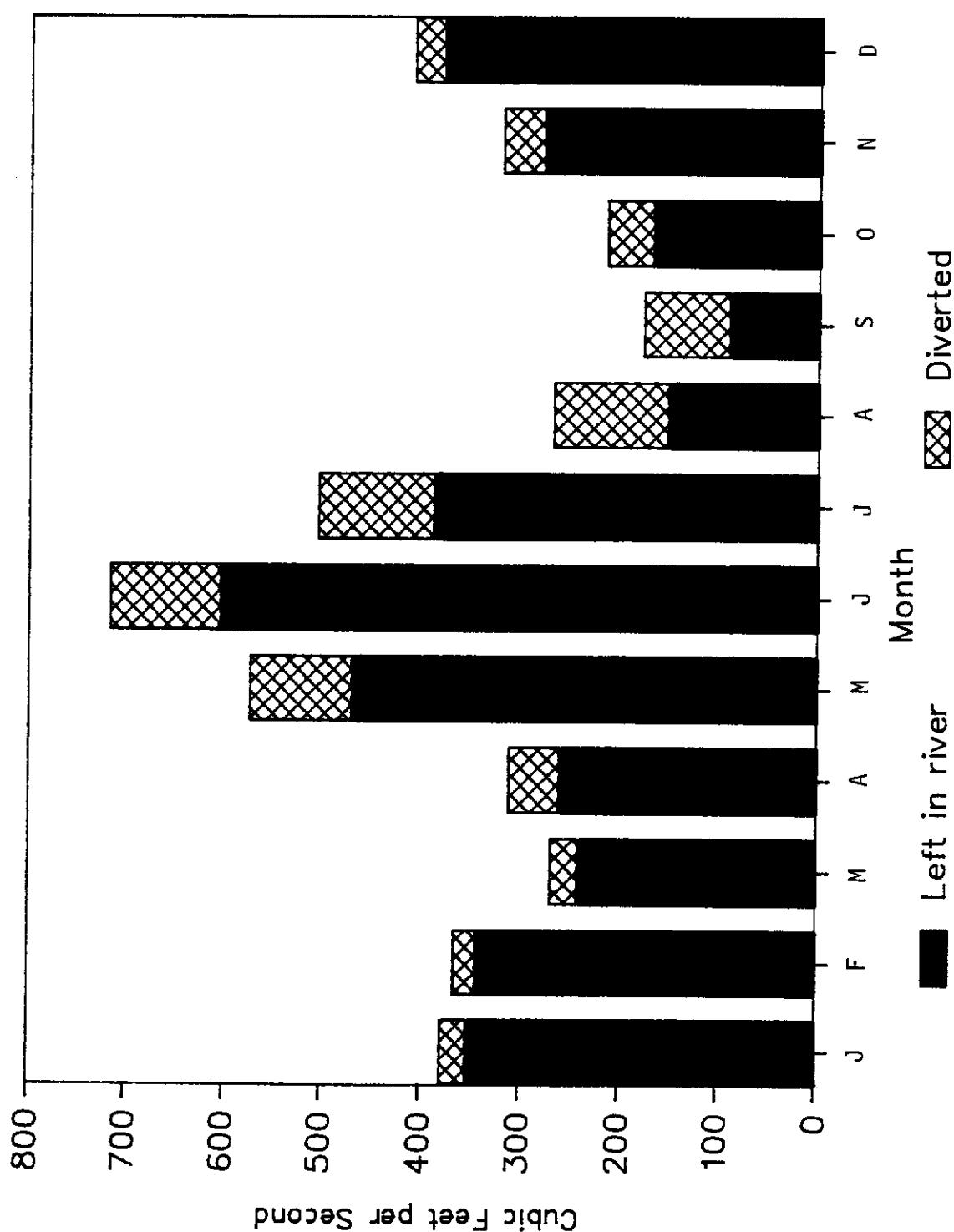
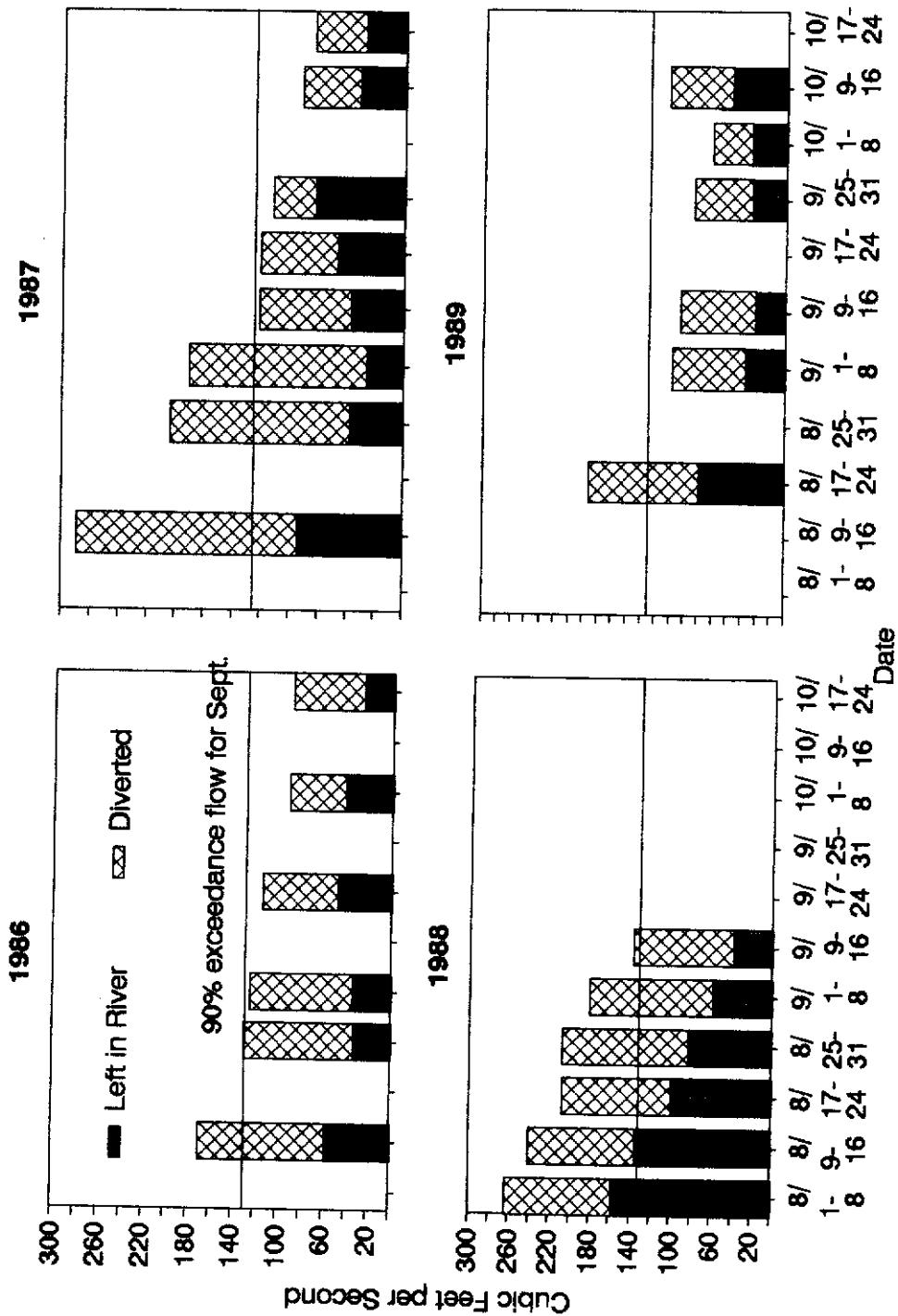


Figure 4. Monthly total irrigation diversion and estimated instream flow downstream of the lowest diversion. Irrigation diversion is the total of measurements on individual ditches between 1979 and 1990. Remaining instream flows were estimated as mean monthly flow at the USGS gage (RM 11.4) minus the irrigation diversion (see Appendix A, Table 1).



**Figure 5. Instantaneous late summer irrigation diversion and instream flow near upper FIM reach.** Irrigation diversion was measured at ditches. Instream flow was usually measured at Woodcock Bridge. When data from this point was unavailable, we substituted discharge measured at 101 Bridge when available. When neither was available, we substituted the gage reading minus the total irrigation diversion. Both substitutes overestimate flow at Woodcock Bridge because the river loses some flow to groundwater between the bridges (see Appendix A, Tables 2 and 3).

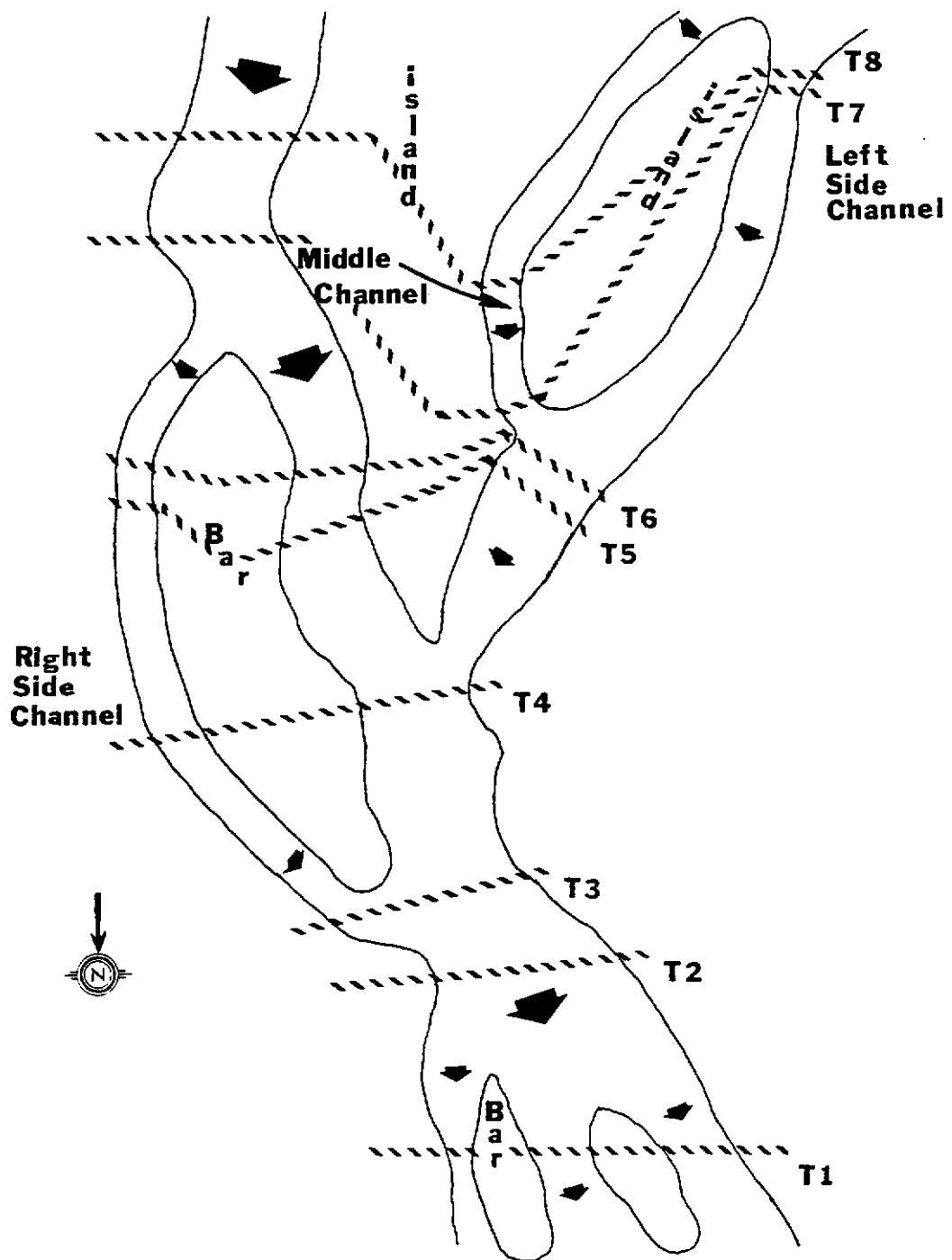


Figure 6. Plan view of the upper IFIM study site at river mile 4.2 on the Dungeness River.

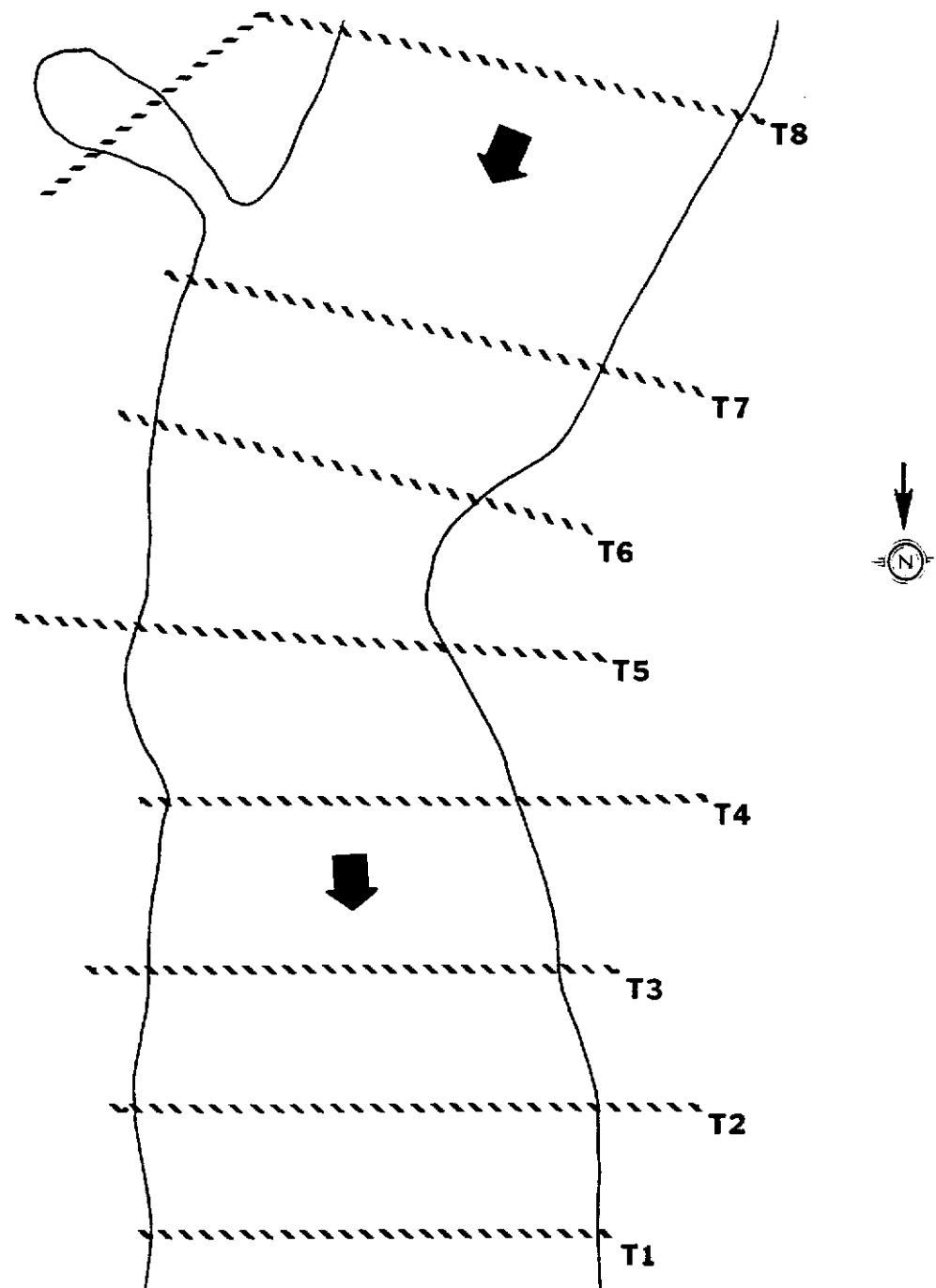
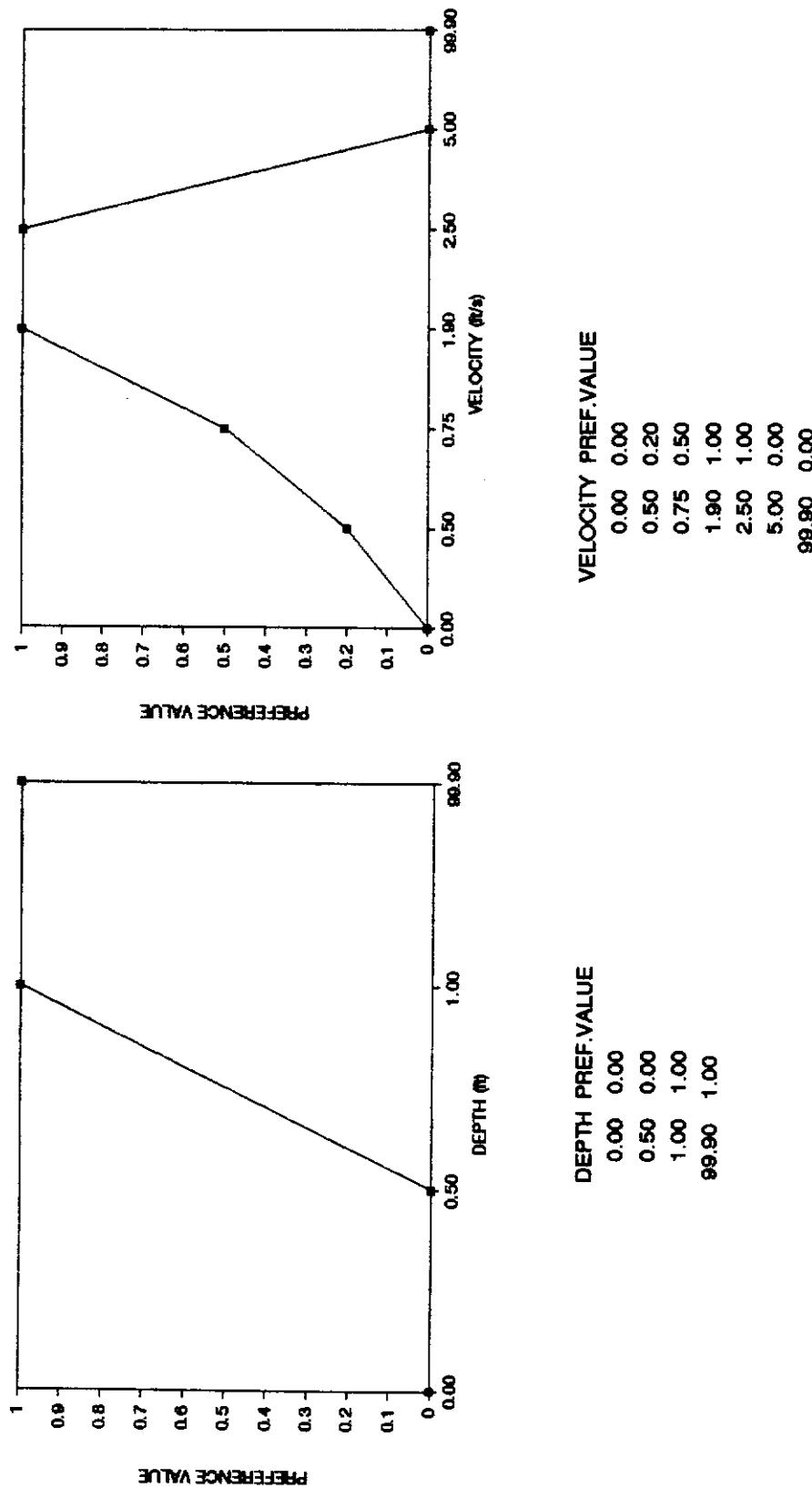


Figure 7. Plan view of the lower IFIM study site at river mile 2.3 on the Dungeness River.

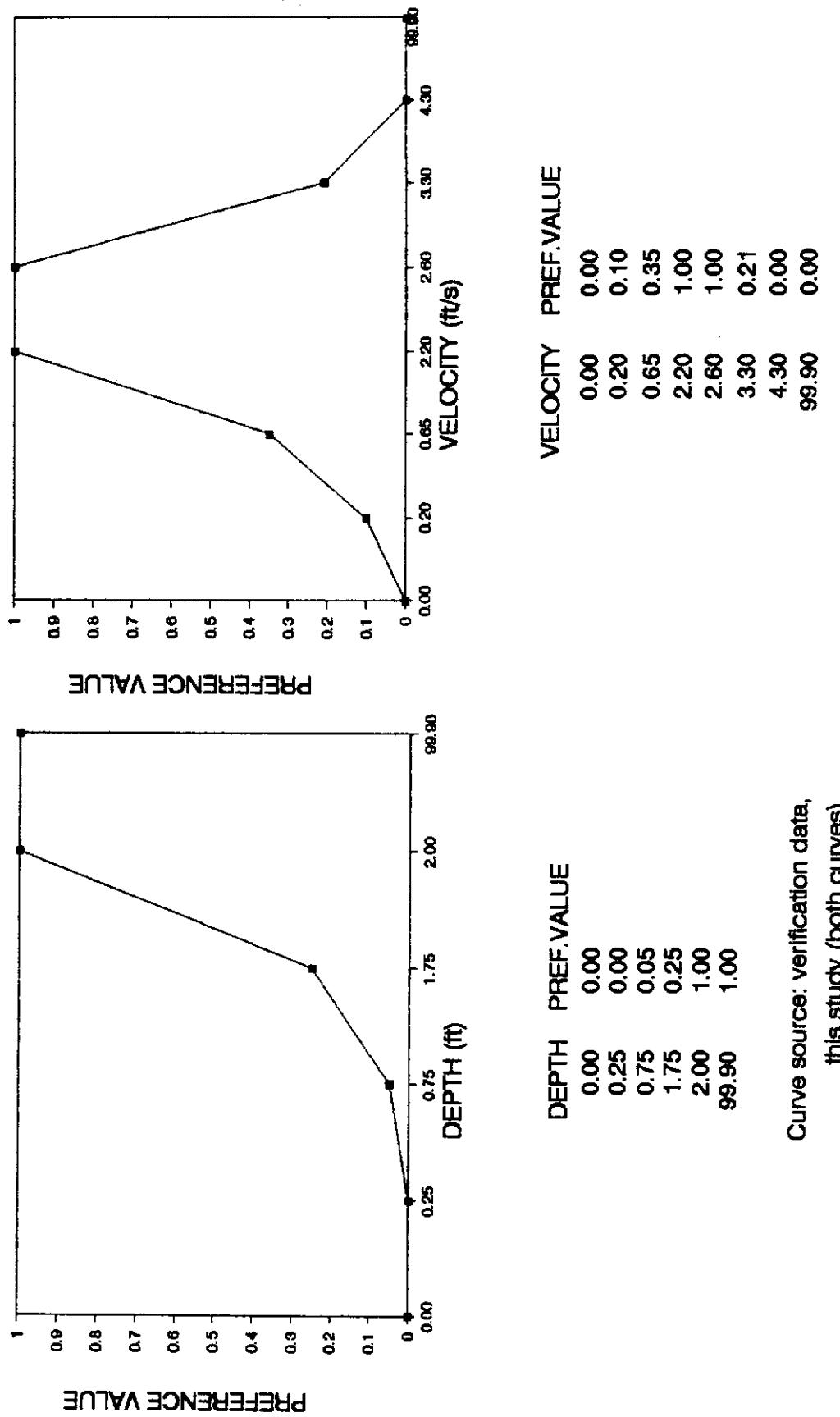
Species	Stage	Month											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Winter steelhead													
	Spawning												
	Juvenile rearing												
	Adult migration/holding												
Dolly varden													
	Juvenile rearing												
Coho													
	Spawning												
	Juvenile rearing												
Spring chinook													
	Spawning												
	Juvenile rearing												
	Adult migration/holding												
Pink													
	Spawning												

Figure 8. Timing of fish species and stages in the Dungeness River.



Curve source: H. Beecher, WDW,  
pers. comm.(both curves)

Figure 9. Steelhead spawning depth and velocity preference curves.



Curve source: verification data,  
this study (both curves)

Figure 10. Steelhead juvenile depth and velocity preference curves.

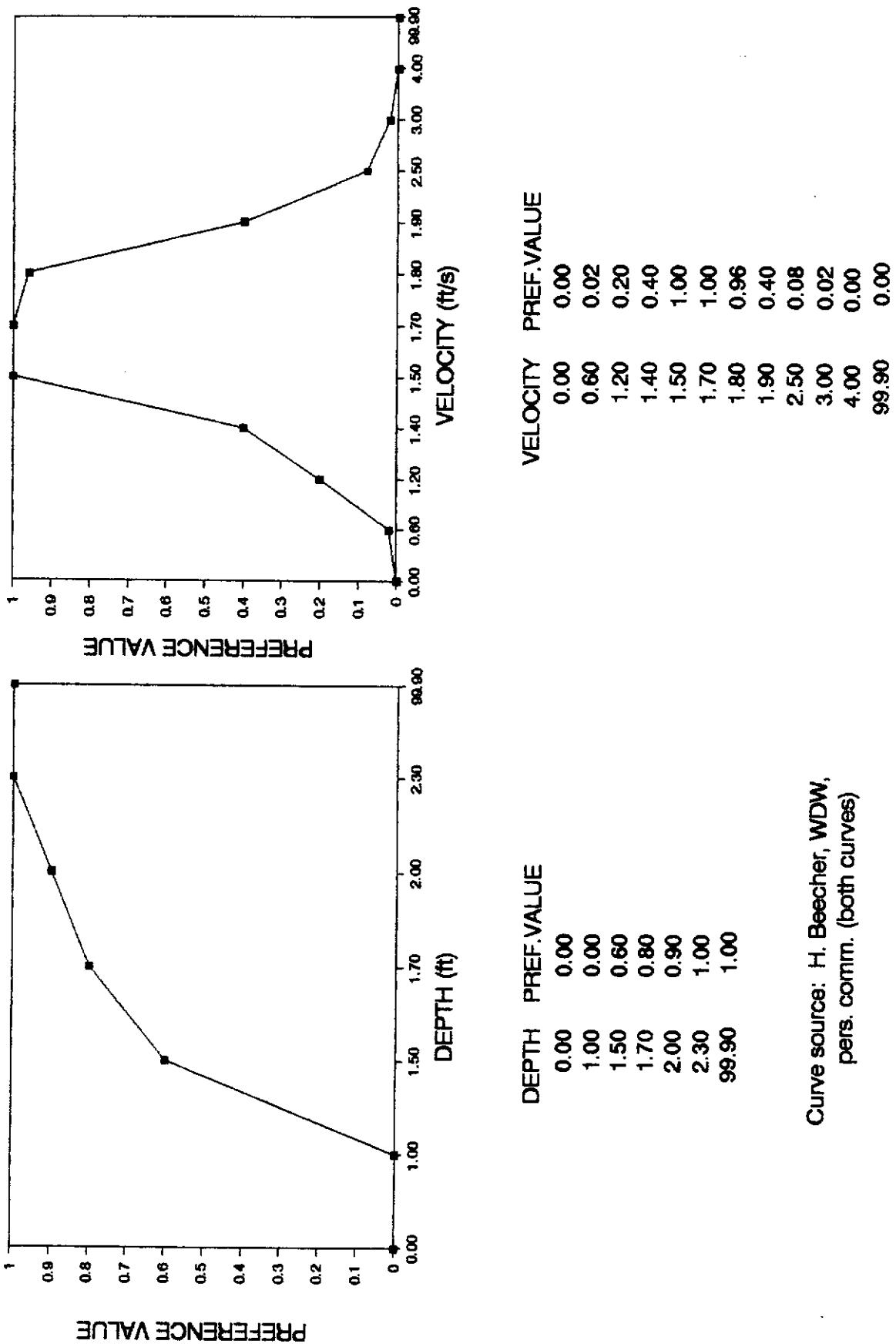
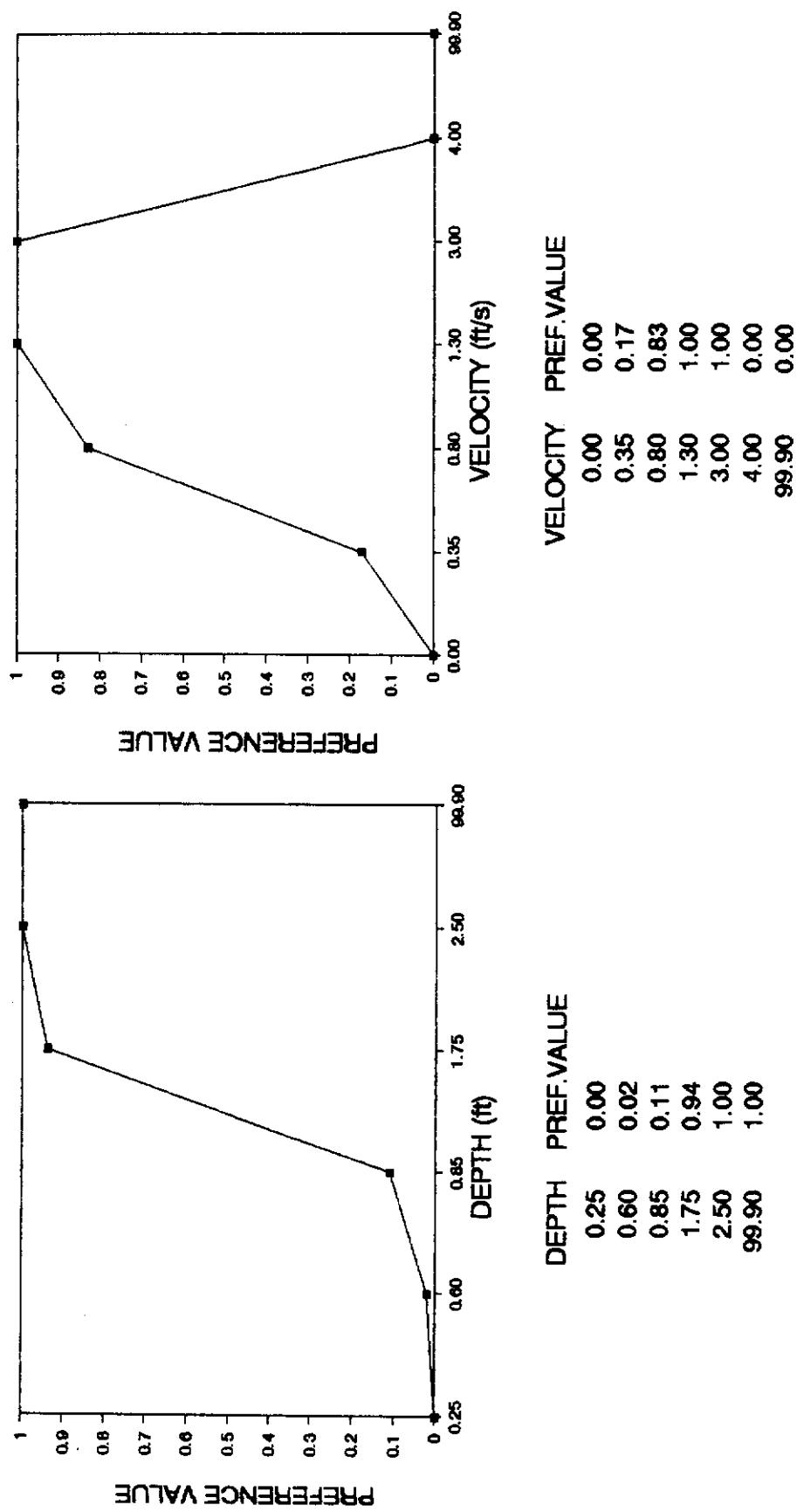
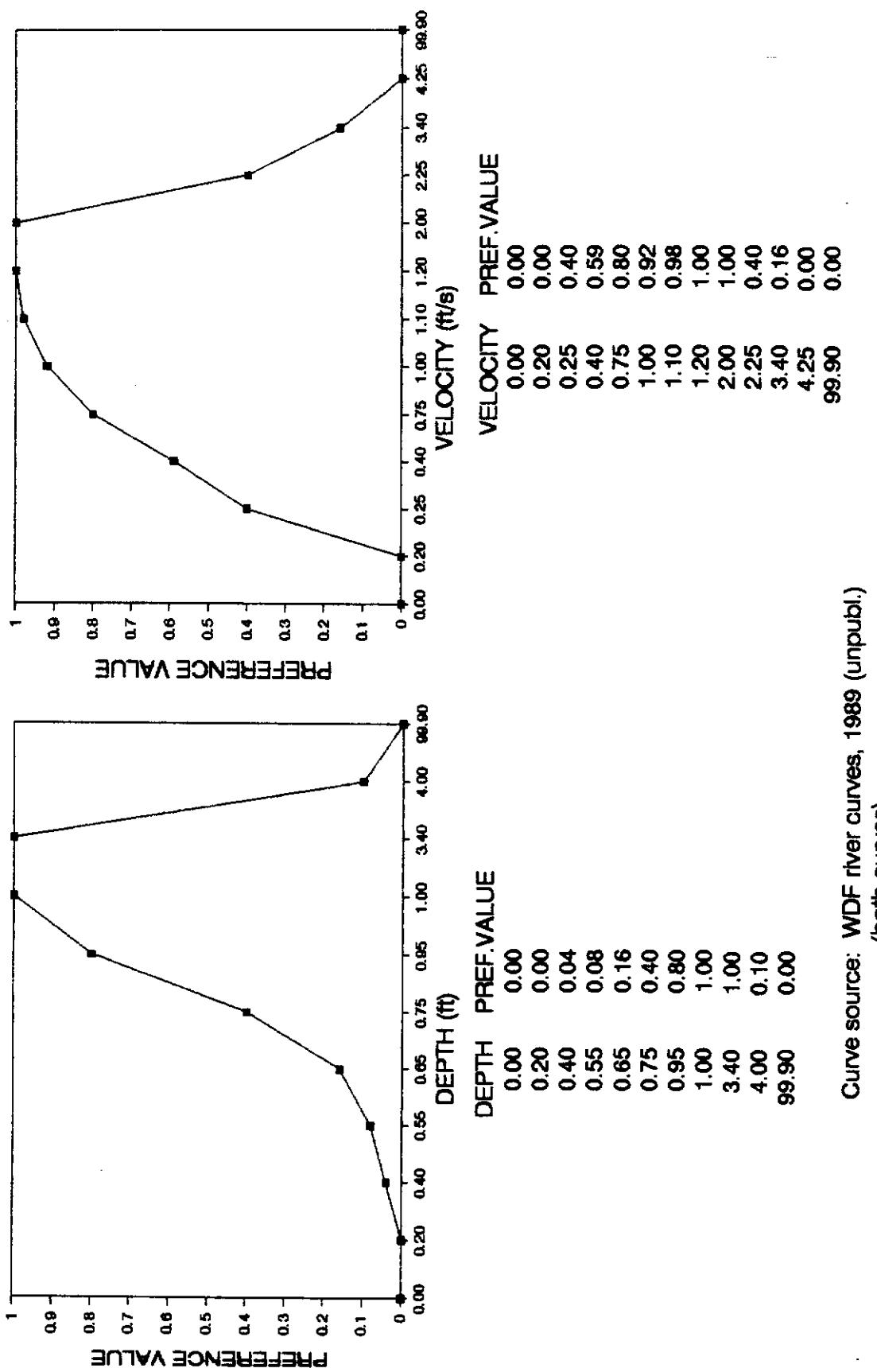


Figure 11. Steelhead adult depth and velocity preference curves.



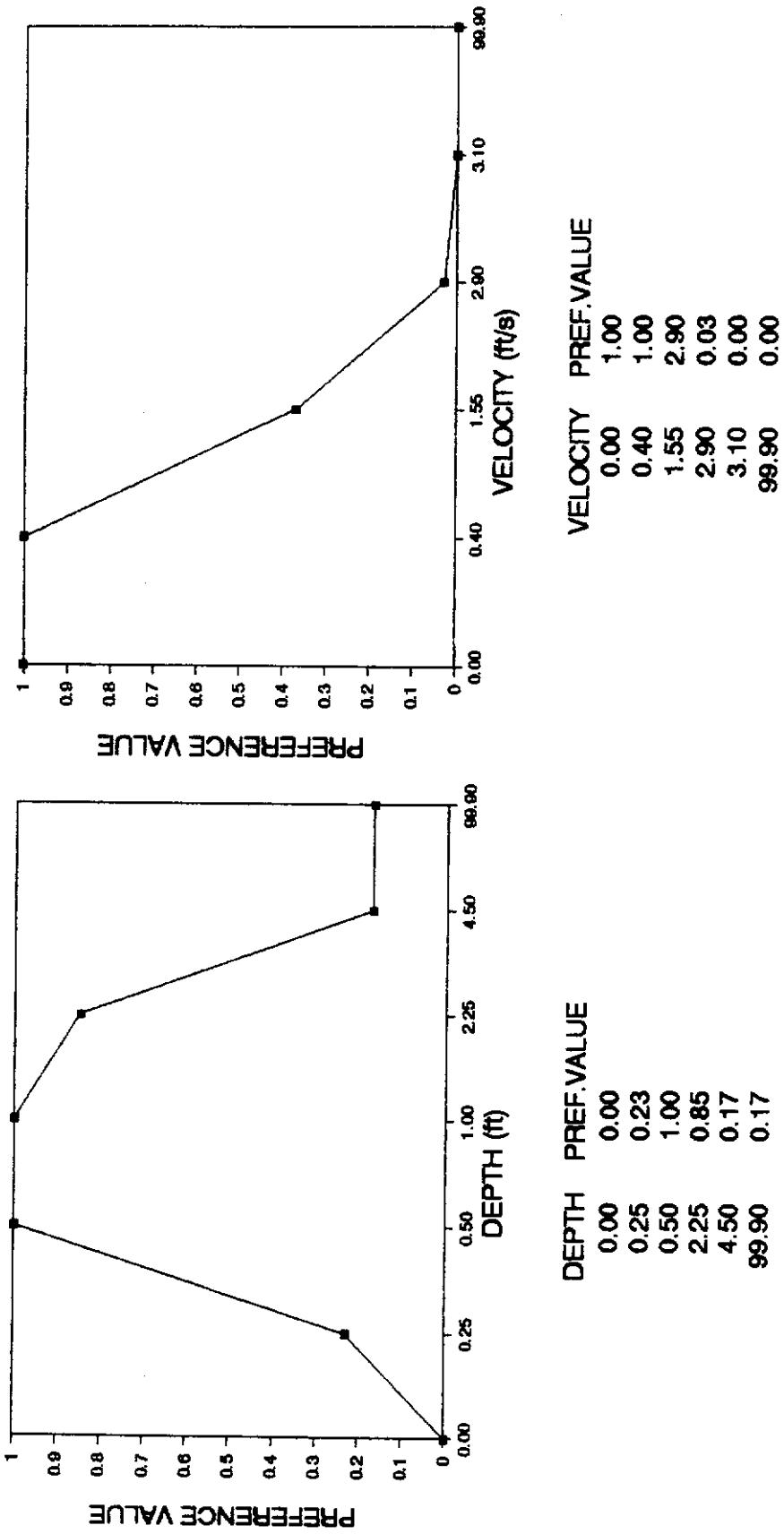
Curve source: H. Beecher, WDW,  
pers. comm. (both curves)

Figure 12. Dolly Varden juvenile depth and velocity preference curves.



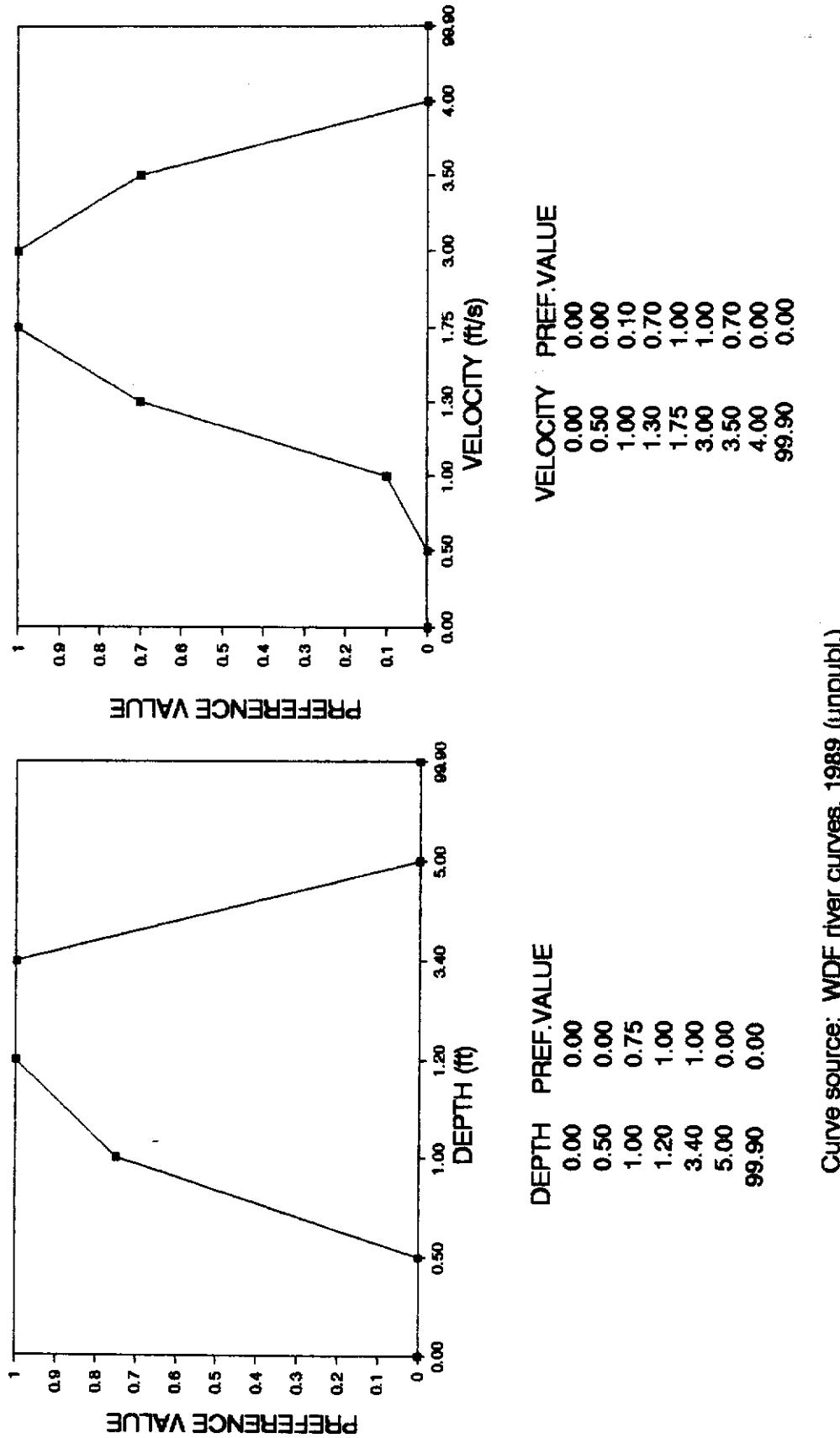
Curve source: WDF river curves, 1989 (unpubl.)  
(both curves)

Figure 13. Coho spawning depth and velocity preference curves.



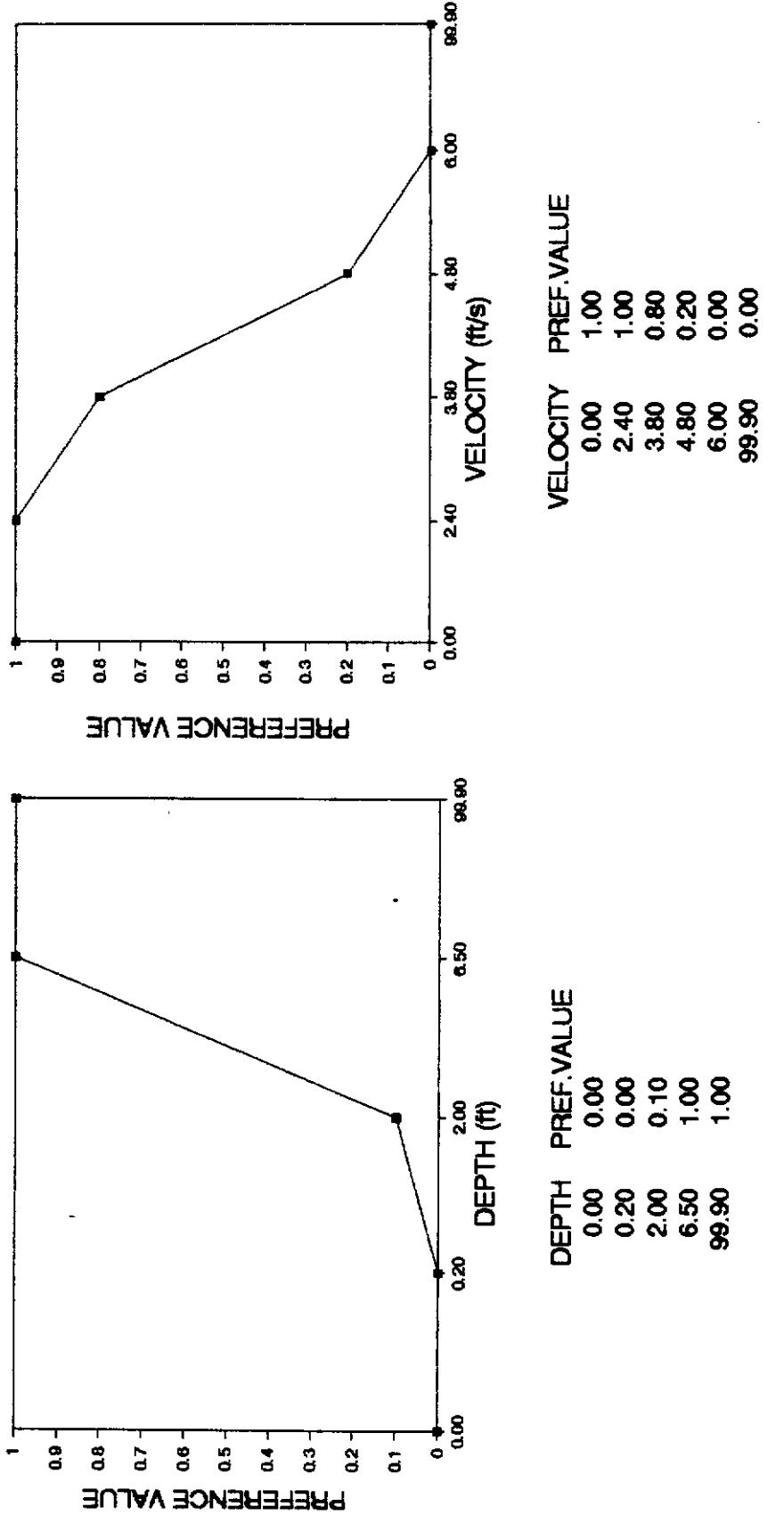
Curve source: verification data,  
this study (both curves)

Figure 14. Coho juvenile depth and velocity preference curves.



Curve source: WDF river curves, 1989 (unpubl.)  
(both curves)

Figure 15. Chinook spawning depth and velocity preference curves.



Curve source: WDF river curves, 1989 (unpubl.)  
(both curves)

Figure 16. Chinook adult depth and velocity preference curves.

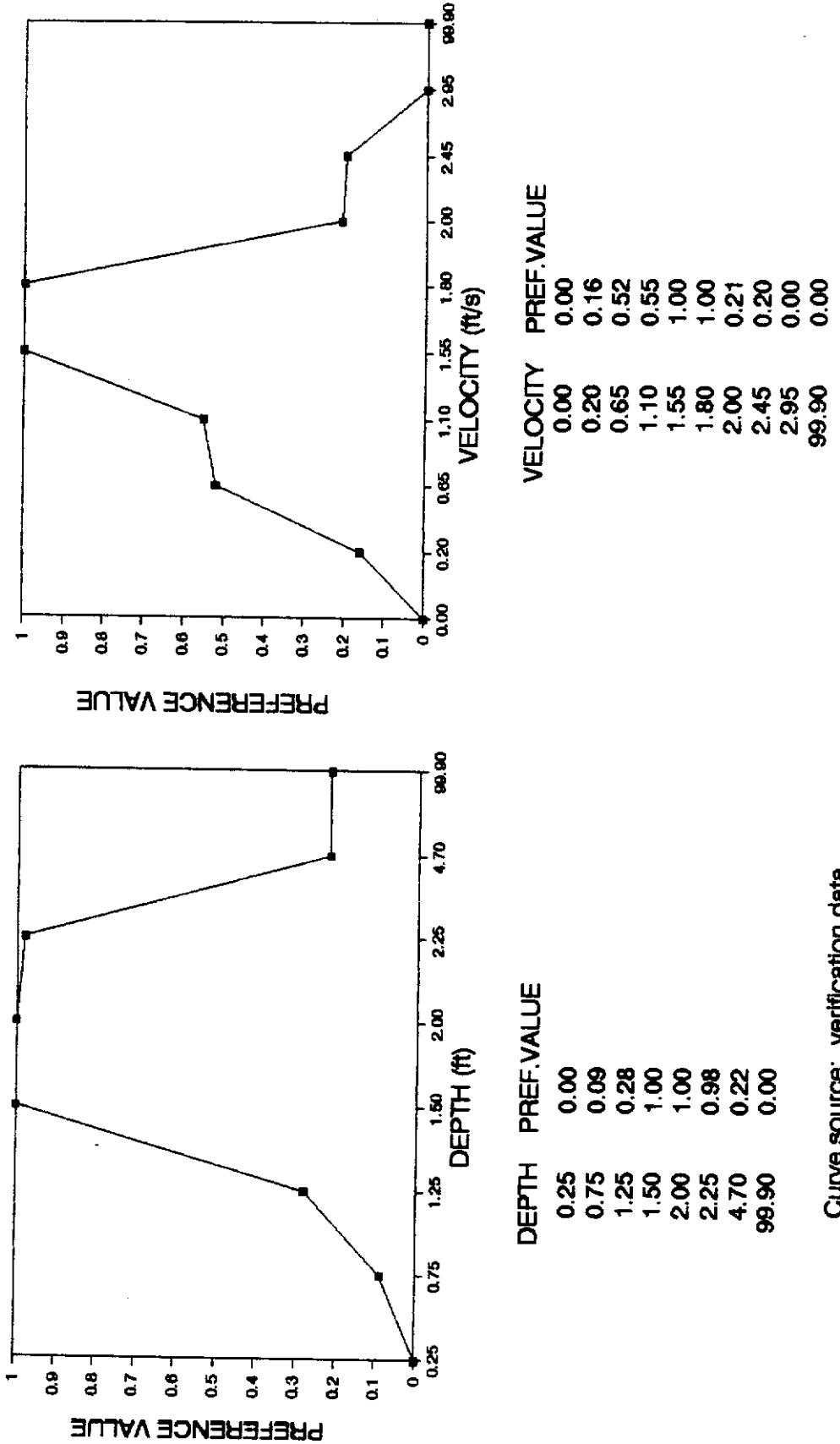
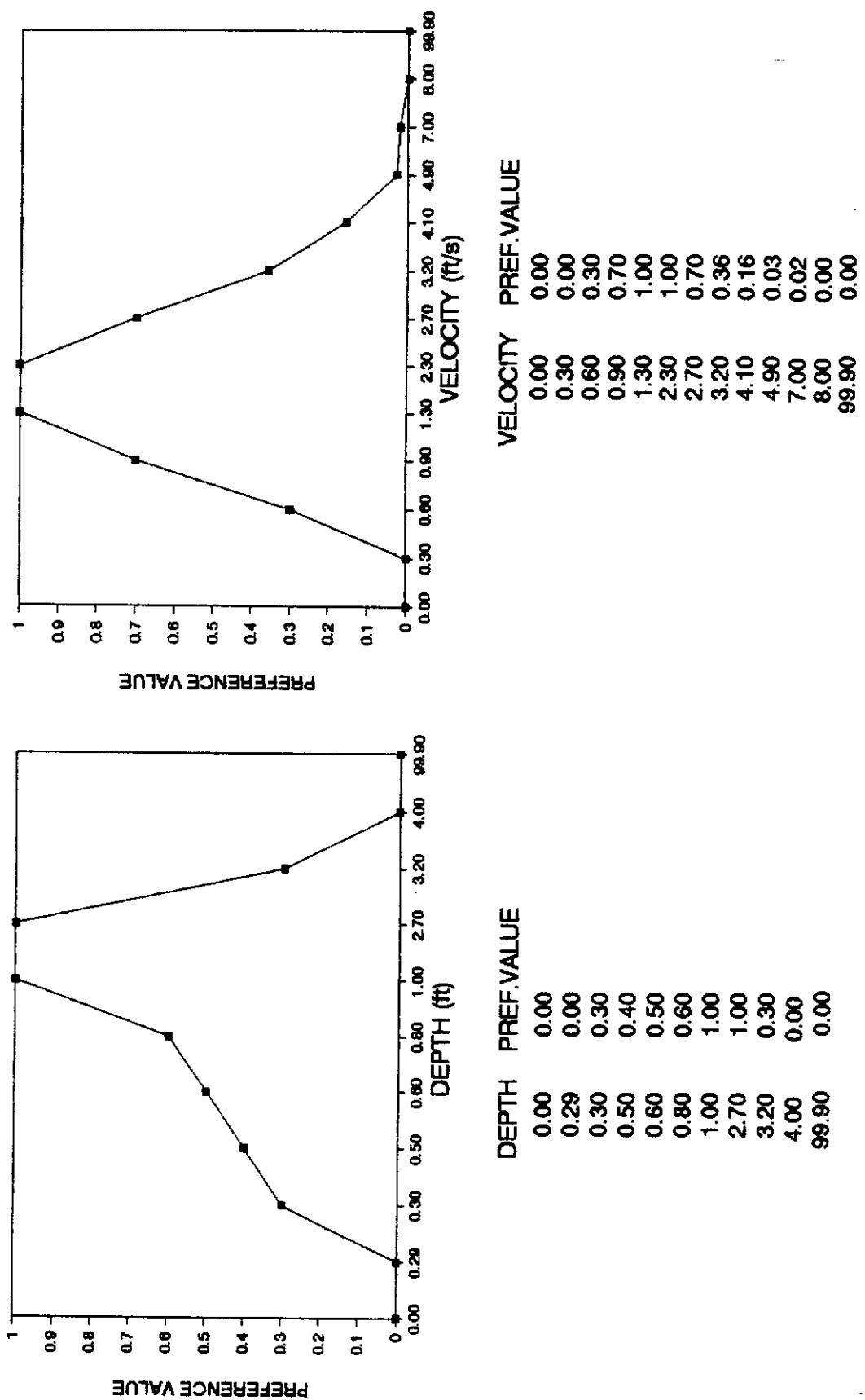


Figure 17. Chinook juvenile depth and velocity preference curves.



Curve source: WDF river curves, 1989  
(unpubl.) (both curves)

Figure 18. Pink spawning depth and velocity preference curves.

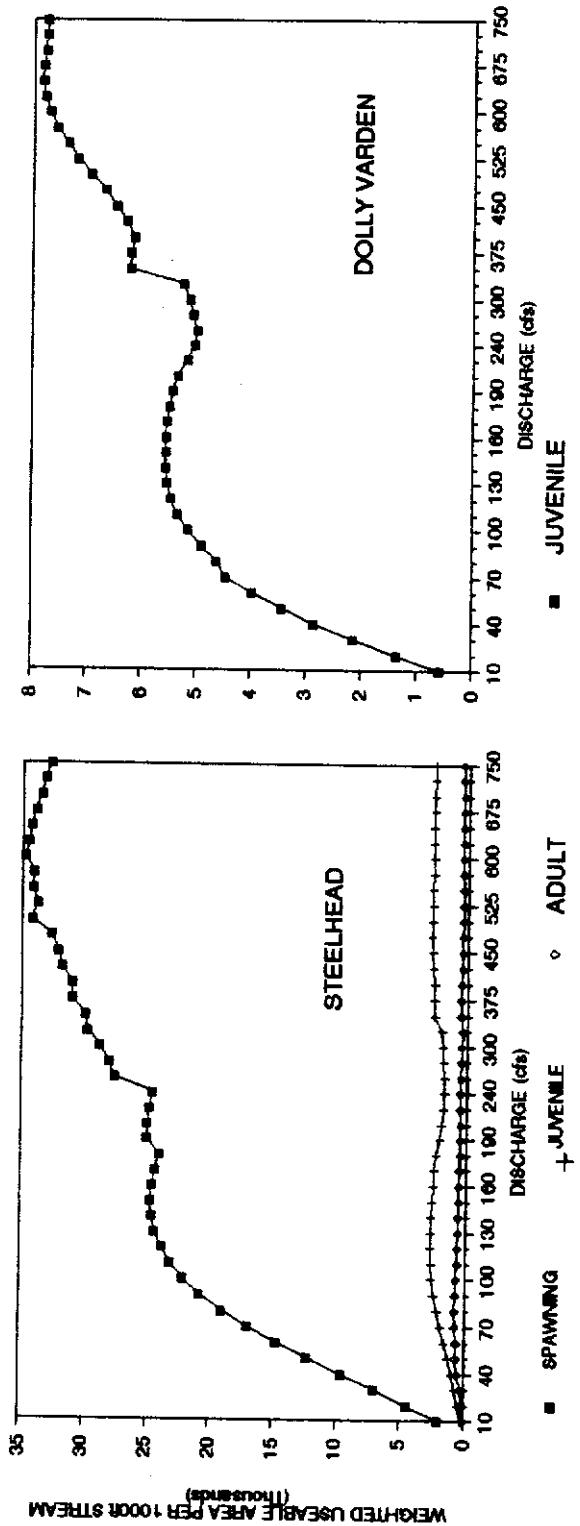


Figure 19. Predicted WUA of habitat for spawning, juvenile and adult steelhead and juvenile Dolly Varden, from the combined models for the upper study site, river mile 4.2.

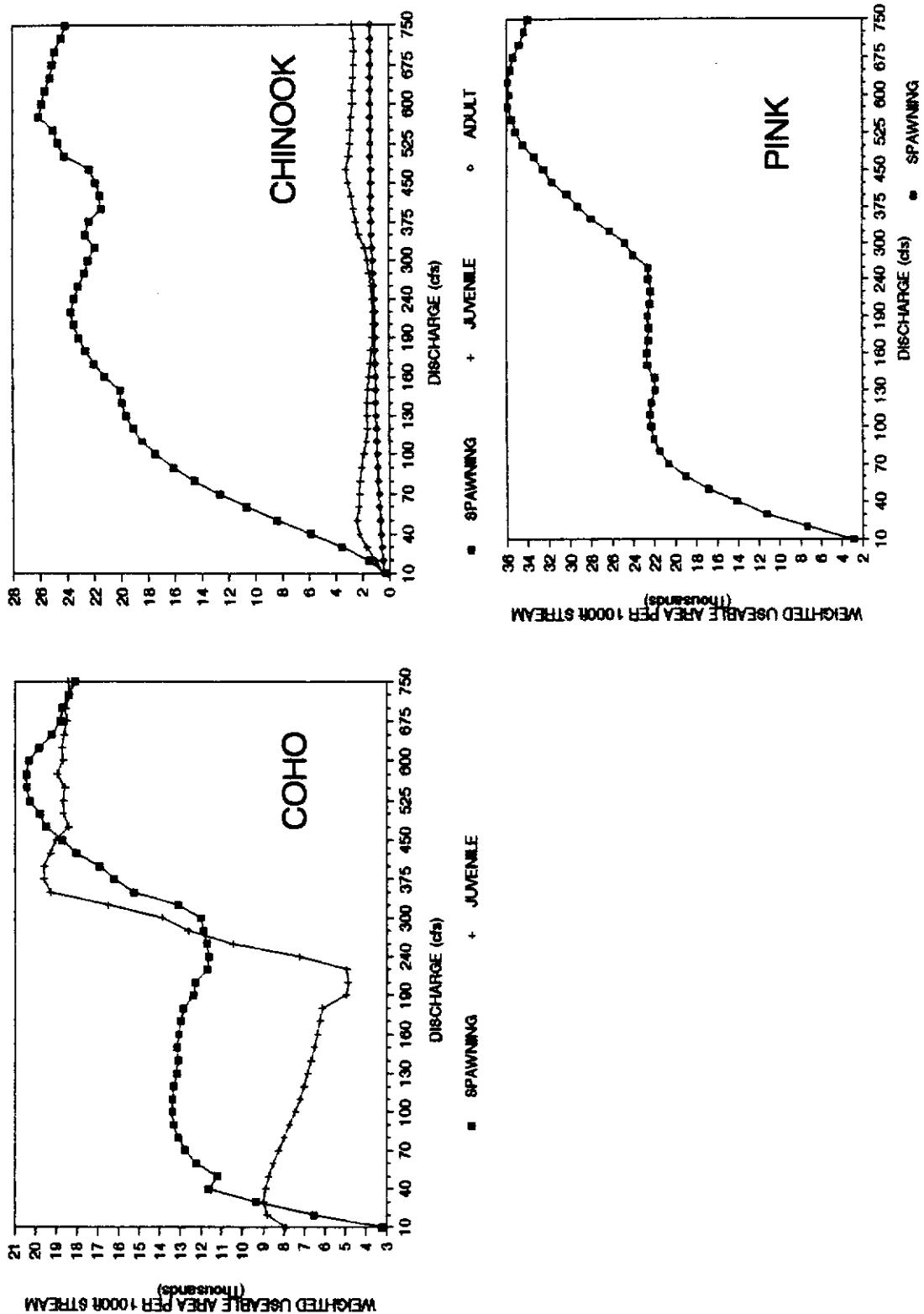


Figure 20. Predicted WUA of habitat for coho, chinook and pink salmon, from the combined models for the upper study site, river mile 4.2.

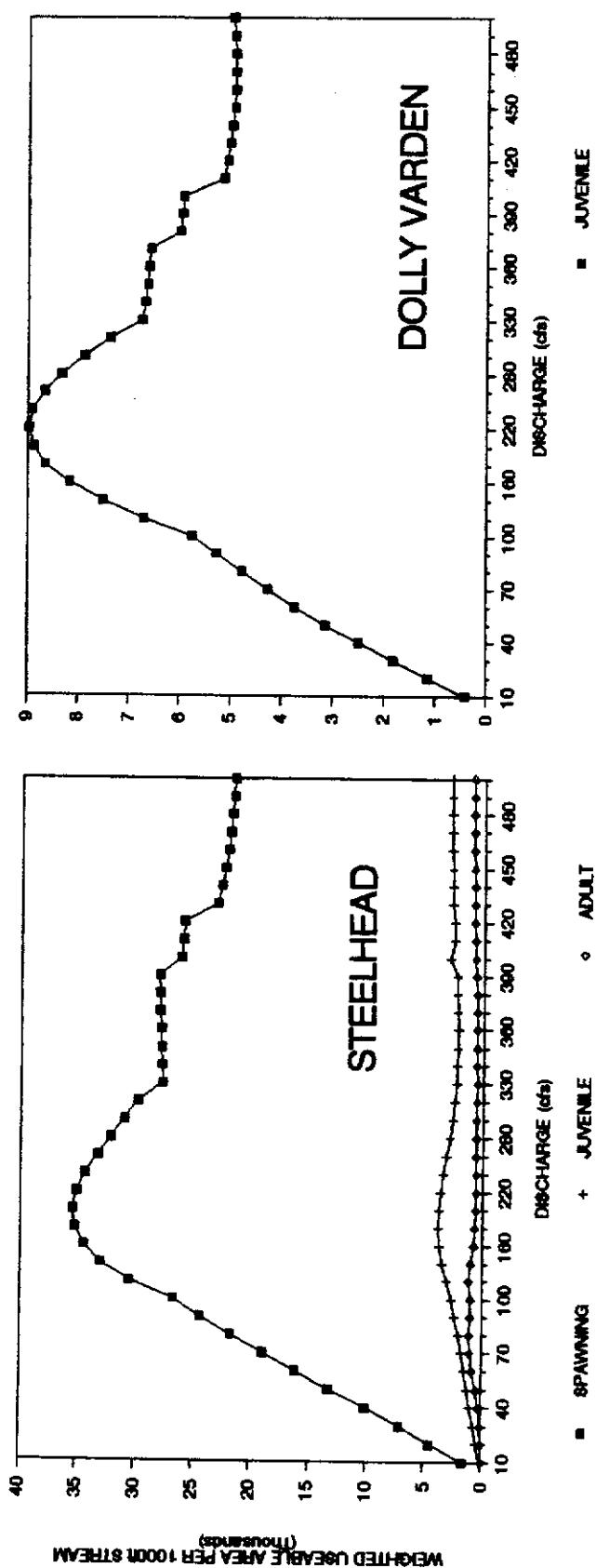


Figure 21. Predicted WUA of habitat for spawning, juvenile and adult steelhead and juvenile Dolly Varden, from the combined models for the lower study site, river mile 2.3.

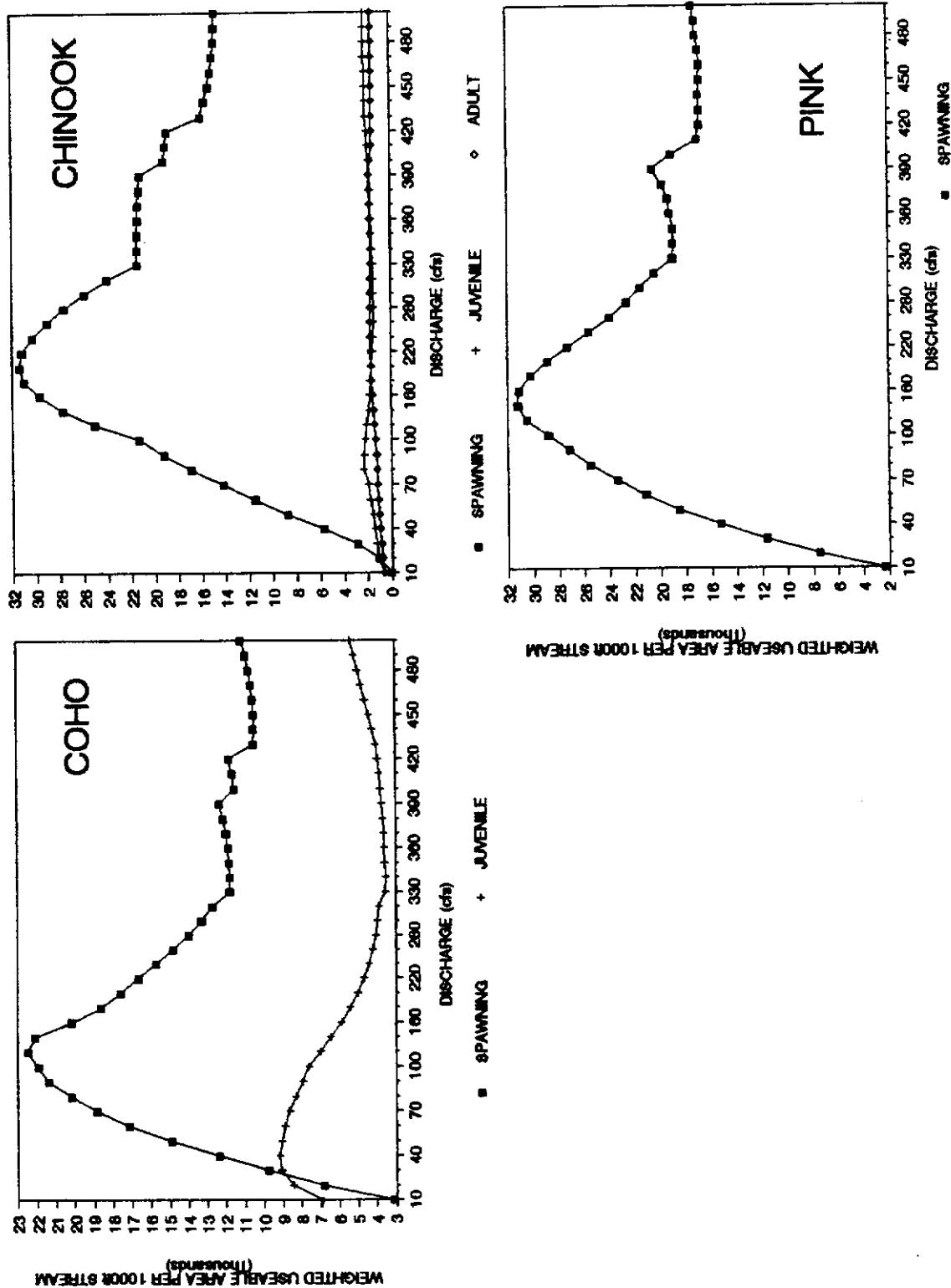


Figure 22. Predicted WUA of habitat for coho, chinook and pink salmon, from the combined models for the lower study site, river mile 2.3.

Table 1. Programs from the USFWS Physical Habitat Simulation System (PHABSIM) used in this study.

Name	Function
CKI4	Checks an IFG4 data set for format errors
CRVFIL	Converts a formatted curves file to a FISHFIL
GCURV	Generates a file of habitat criteria curves
HABTAT	Generates from TAPE3, TP4, ZHABIN and FISHFIL predictions of WUA vs. discharge per 1000 ft stream
IFG4	Produces the hydraulic input files TAPE3 and TP4 for the HABTAT program
IFG4IN	Builds an IFG4 data file
ZHABIN	Builds an input/output options file required by HABTAT

Table 2. Dates of data collection at the study sites.

Hydraulic data				Criteria curve data			
Target flow	Measured discharge	Upper site	Lower site	Target flow	Measured discharge	Upper site	Lower site
High	720	June 20,21,1988		Low	50	Sept. 6,7,1988	
High	441		June 29,1988				
Medium	325	July 25,26,1988		Low	127	July 27,1989	
Medium	351		July 26,1988				
Low	32	Sept. 12,1988					
Low	37		Sept. 13,1988				

Table 3. Data files required to model hydraulics of the upper and lower study sites.

Upper site			Lower site		
Channel	Measured velocity set used (cfs)	In-channel flow range to model (cfs)	Channel	Measured velocity set used (cfs)	In-channel flow range to model (cfs)
Main	32	10-150	Main	35.5	10-150
Main	326	150-330	Main	351.5	150-360
Main	326	320-520	Main	351.5	300-400
Main	703	520-710	Main	441	400-500
Right T 1	8	1-30			
Right T 1	49	30-60			
Right T 3-6	21.5	1-30			
Left T 5-8	18	1-40			
Left T 5-8	75	30-200			
Middle T 7,8	3	1-8			

**Table 4.** Hydraulic model calibration details for each model, including  
(1) changes in either cell velocities or Manning's N values, and  
(2) velocity adjustment factors for each transect.

Upper Dungeness site      Calibration information for calculated discharges

Data file =                            MAINMED2

Measured discharge =                32 cfs

Transect number								
1	2	3	4	5	6	7	8	
Discharge								
36.5	25.8	30.2	35.7	36.6	32.8	29.3	28.9	
Stage								
189.9	190.8	191	191.1	191.5	191.54	193.7	194	
Plotting stage								
1.69	0.92	1.03	1.08	1.37	1.44	0.81	1.06	
Stage/discharge relationship (S vs Q)      S=A*Q**B+SZF								
A =	1.1093	0.4414	0.4624	0.4124	0.4609	0.5102	0.2487	0.4167
B =	0.1170	0.2260	0.2351	0.2692	0.3026	0.2973	0.3497	0.2774
SZF =	188.2	189.9	190	190	190.1	190.1	192.9	192.9
B coefficient LOG(LOG discharge/stage relationship)								
8.54	4.42	4.25	3.72	3.31	3.36	2.86	3.61	
=====								

Upper Dungeness site      Changes made in cells for calibration

Data file =                            MAINMED2

Changed			
Transect	Vertical	From	To
1	9	Vel=.01	0
1	11	Vel=.01	0
1	12	Vel=.01	0
1	32	N=0	0.9
2	12	N=0	0.9
2	26	N=0	0.9
2	28	N=0	0.9
4	8	Vel=0	0.1
4	10	Vel=0	0.1
5	22	Vel=.01	0
8	14	Vel=.01	0.05
8	15	Vel=.01	0
8	16	Vel=.01	0
8	17	Vel=.01	0
8	18	Vel=.01	0

Upper Dungeness site      Velocity adjustment factors  
Data file =                  MAINMED2  
Measured discharge =        32 cfs

Transect	Flow	VAF
1	31.6	0.982
1	224	2.149
2	31.6	1.006
2	224	2.131
3	31.6	0.999
3	224	2.356
4	31.6	0.997
4	224	2.952
5	31.6	0.999
5	224	1.711
6	31.6	0.996
6	224	1.989
7	31.6	0.995
7	224	1.292
8	31.6	0.998
8	224	2.707

Upper Dungeness site

Calibration information for calculated discharges

Data file = MAINM1B

Measured discharge = 326 cfs

Transect number								
1	2	3	4	5	6	7	8	
Discharge								
330.8	369.7	384.1	307	311.3	297.8	302.8	303.1	
Stage								
190.5	191.7	192	192	192.7	192.9	194.8	195	
Plotting stage								
2.31	1.82	2.01	2.02	2.63	2.84	1.85	2.13	
Stage/discharge relationship (S vs Q)							$S=A*Q^{**}B+SZF$	
A =	0.5594	0.1858	0.2276	0.1832	0.4279	0.3296	0.2114	0.1821
B =	0.2444	0.3859	0.3660	0.4191	0.3163	0.3780	0.3797	0.4304
SZF =	188.2	189.9	190	190	190.1	190.1	192.9	192.9
B coefficient LOG/LOG discharge/stage relationship								
4.09	2.59	2.73	2.39	3.16	2.64	2.63	2.32	

=====

Upper Dungeness site

Changes made in cells for calibration

Data file = MAINM1B

Changed

Transect	Vertical	From	To
4.5	10	N=0	4.0
4.5	46	N=0	0.3
5.0	7	N=0	0.2
8.0	5	N=0	0.2

Upper Dungeness site      Velocity adjustment factors  
 Data file =                  MAINM1B  
 Measured discharge =        326 cfs

Transect	Flow	VAF
1	80	0.679
1	224	0.920
1	328.4	1.002
2	80	1.540
2	224	1.041
2	328.4	0.999
3	80	0.766
3	224	0.898
3	328.4	1.002
4	80	0.642
4	224	0.897
4	328.4	1.002
5	80	0.753
5	224	0.928
5	328.4	1.001
6	80	0.790
6	224	0.945
6	328.4	1.001
7	80	0.929
7	224	0.970
7	328.4	1.001
8	80	0.856
8	224	0.962
8	328.4	1.000

Upper Dungeness site

Calibration information for calculated discharges

Data file = MAINMED3

Measured discharge = 326 cfs

Transect number							
1	2	3	4	5	6	7	8
Discharge							
330.8	369.7	384.1	307	311.3	297.8	302.8	303.1
190.5	191.7	Stage 192	192	192.7	192.9	194.8	195
Plotting stage							
2.31	1.82	2.01	2.02	2.63	2.84	1.85	2.13
Stage/discharge relationship (S vs Q)						$S=A*Q^{**}B+SZF$	
A =	0.9132	0.3974	0.6267	0.2833	0.6862	0.9763	0.3343 0.8419
B =	0.1600	0.2573	0.1959	0.3430	0.2340	0.1874	0.2995 0.1625
SZF =	188.2	189.9	190	190	190.1	190.1	192.9 192.9
B coefficient LOG/LOG discharge/stage relationship							
6.25	3.89	5.11	2.92	4.27	5.33	3.34	6.16

=====

Upper Dungeness site

Changes made in cells for calibration

Data file = MAINMED3

Transect	Vertical	From	To	Changed
1	5	N=0	0.1	
1	20	N=0	0.05	
1	21	N=0	0.05	
3	29	N=0	0.1	
5	7	N=0	0.2	
5	19	Vel=4.8	4.6	
5	30	N=0	0.2	
6	5	N=0	0.2	
6	26	N=0	0.2	
8	5	N=0	0.2	

Upper Dungeness site      Velocity adjustment factors  
 Data file =                  MAINMED3  
 Measured discharge =        326 cfs

Transect	Flow	VAF
1	326	1.000
1	525	1.287
1	718.5	1.526
2	326	1.000
2	525	1.163
2	718.5	1.295
3	326	1.000
3	525	1.232
3	718.5	1.415
4	326	1.000
4	525	1.283
4	718.5	1.506
5	326	1.000
5	525	1.243
5	718.5	1.440
6	326	1.000
6	525	1.348
6	718.5	1.641
7	326	1.000
7	525	1.134
7	718.5	1.238
8	326	1.000
8	525	1.430
8	718.5	1.810

Upper Dungeness site

## Calibration information for calculated discharges

Data file = MAINHIGH

Measured discharge = 703 cfs

Transect number								
1	2	3	4	5	6	7	8	
Discharge								
770.6	773.3	669.2	763.3	701.2	693.5	582	725.9	
Stage								
190.8	192.1	192.3	192.8	193.3	193.4	195.2	195.4	
Plotting stage								
3.04	2	2.15	2.65	3.17	3.3	2.5	2.65	
Stage/discharge relationship (S vs Q) S=A*Q**B+SZF								
A =	1.2320	0.2995	0.5371	0.2531	0.7024	1.0326	0.4316	1.0038
B =	0.1359	0.2855	0.2132	0.3538	0.2300	0.1776	0.2727	0.1474
SZF =	187.8	190.1	190.1	190.1	190.1	190.1	192.7	192.7
B coefficient LOG/LOG discharge/stage relationship								
7.36	3.5	4.69	2.83	4.35	5.63	3.67	6.79	

Upper Dungeness site

## Changes made in cells for calibration

Data file = MAINHIGH

Transect	Vertical	Changed	
		From	To
1	24	Vel=3.6	3.65
1	43	Vel=7.48	7.68
1	44	Vel=8.53	8.73
1	45	Vel=8.48	8.68
1	46	Vel=7.92	8.12
1	47	Vel=8.33	8.53
1	49	Vel=7.76	7.96
1	53	Vel=0.10	0.05
2	3	Vel=0.10	0.20
2	4	Vel=0.20	0.10
2	12	Vel=4.90	4.94
2	24	Vel=2.50	2.58
3	6	Vel=1.91	1.61
3	7	Vel=2.33	2.13

(Continued)

Upper Dungeness site

Changes made in cells for calibration

Data file =

MAINHIGH

Transect	Vertical	From	To	Changed
3	24	Vel=4.40	4.45	
3	8	Vel=4.56	4.36	
3	9	Vel=5.69	5.49	
3	10	Vel=5.89	5.69	
3	11	Vel=6.46	6.06	
3	12	Vel=6.70	6.57	
3	13	Vel=6.73	6.53	
3	14	Vel=7.36	7.16	
3	15	Vel=7.33	7.03	
3	17	Vel=6.51	6.31	
3	18	Vel=5.89	5.69	
3	19	Vel=5.50	5.30	
3	20	Vel=5.25	5.15	
4	5	N=0.00	0.20	
4	14	Vel=7.34	7.54	
4	15	Vel=7.28	7.48	
4	16	Vel=6.97	7.17	
4	20	Vel=7.72	7.92	
4	21	Vel=7.84	8.04	
4	24	Vel=2.57	2.57	
4	28	Vel=0.30	0.20	
5	7	Vel=0.10	0.05	
5	11	Vel=8.54	8.74	
5	12	Vel=9.75	9.95	
5	13	Vel=9.55	9.75	
5	14	Vel=8.95	9.15	
5	15	Vel=8.40	8.60	
5	16	Vel=7.80	8.02	
5	17	Vel=8.08	8.28	
6	9	Vel=8.70	9.18	
6	10	Vel=7.95	8.67	
6	11	Vel=6.91	8.11	
6	12	Vel=7.20	7.40	
6	13	Vel=7.12	7.32	
6	14	Vel=7.00	7.22	
6	15	Vel=7.04	7.24	
6	16	Vel=7.07	7.27	
6	18	Vel=7.22	7.42	
6	29	N=0.00	0.15	
7	20	Vel=0.20	0.10	
8	7	Vel=3.23	3.32	
8	8	Vel=4.20	4.29	
8	15	Vel=7.00	7.20	
8	16	Vel=7.64	7.84	
8	17	Vel=8.17	8.37	
8	18	Vel=7.11	7.31	
8	20	Vel=8.70	8.92	

Upper Dungeness site      Velocity adjustment factors  
 Data file =                  MAINHIGH  
 Measured discharge =        703 cfs

Transect	Flow	VAF
1	328.4	0.608
1	525	0.826
1	718.5	1.014
2	328.4	0.772
2	525	0.902
2	718.5	1.008
3	328.4	0.724
3	525	0.883
3	718.5	1.009
4	328.4	0.668
4	525	0.858
4	718.5	1.011
5	328.4	0.688
5	525	0.864
5	718.5	1.011
6	328.4	0.586
6	525	0.815
6	718.5	1.015
7	328.4	0.807
7	525	0.918
7	718.5	1.006
8	328.4	0.546
8	525	0.792
8	718.5	1.017

Upper Dungeness site      Calibration information for calculated discharges

Data file =                    UDNRCM1

Measured discharge =        8 cfs

Transect number							
1	2	3	4	5	6	7	8

Discharge  
7.7      7.7

Stage  
89.1      89.1

Plotting stage  
0.88      0.88

Stage/discharge relationship (S vs Q)     $S=A*Q^{**}B+SZF$

A =      0.3704    0.3704  
B =      0.4246    0.4246  
SZF =     88.2      88.2

B coefficient LOG/LOG discharge/stage relationship  
2.36      2.36

=====

Upper Dungeness site      Changes made in cells for calibration

Data file =                    UDNRCM1

Changed

Transect	Vertical	From	To
----------	----------	------	----

--no changes required--

Upper Dungeness site      Velocity adjustment factors  
Data file =      UDNRCM1  
Measured discharge =      8 cfs

Transect	Flow	VAF
1	3.2	1.008
1	8.1	0.993
1	49.0	1.124
2	3.2	1.008
2	8.1	0.993
2	49.0	1.124

Upper Dungeness site      Calibration information for calculated discharges

Data file =                  UDNRCH1

Measured discharge =        49 cfs

Transect number							
1	2	3	4	5	6	7	8

47.8	47.8	Discharge
------	------	-----------

89.7	89.7	Stage
------	------	-------

1.6	1.6	Plotting stage
-----	-----	----------------

Stage/discharge relationship (S vs Q)     $S=A*Q^{**}B+SZF$

A =        0.3631    0.3631

B =        0.3835    0.3835

SZF =      88.1      88.1

B coefficient LOG/LOG discharge/stage relationship  
2.61      2.61

=====

Upper Dungeness site      Changes made in cells for calibration

Data file =                  UDNRCH1

Changed

Transect	Vertical	From	To
----------	----------	------	----

--no changes required--

Upper Dungeness site      Velocity adjustment factors  
Data file =                  UDNRCH1  
Measured discharge =        49 cfs

Transect	Flow	VAF
1	8.1	0.732
1	49.4	1.000
2	8.1	0.732
2	49.4	1.000

Upper Dungeness site      Calibration information for calculated discharges

Data file =                  UDNRCH36

Measured discharge =        21.5 cfs

Transect number							
1	2	3	4	5	6	7	8

Discharge							
22.6	26.1	23.6	19.6				

Stage							
92.2	92.3	93.4	93.6				

Plotting stage							
1.2	1.29	0.94	0.95				

Stage/discharge relationship (S vs Q)     $S=A*Q^{**}B+SZF$

A =    0.7278    0.7731    0.4210    0.4378

B =    0.1603    0.1569    0.2541    0.2603

SZF =    91        91        92.5      92.6

B coefficient LOG/LOG discharge/stage relationship							
6.24	6.37	3.94	3.84				

Upper Dungeness site      Changes made in cells for calibration

Data file =                  UDNRCH36

Changed

Transect	Vertical	From	To
----------	----------	------	----

--no changes required--

Upper Dungeness site      Velocity adjustment factors  
Data file =      UDNRCH36  
Measured discharge =      21.5 cfs

Transect	Flow	VAF
1	0.3	0.126
1	8.6	0.590
1	21.5	1.000
1	43.0	1.500
2	0.3	0.103
2	8.6	0.605
2	21.5	1.000
2	43.0	1.433
3	0.3	0.219
3	8.6	0.730
3	21.5	1.000
3	43.0	1.270
4	0.3	0.253
4	8.6	0.703
4	21.5	1.000
4	43.0	1.326

Upper Dungeness site

Calibration information for calculated discharges

Data file = UDNML58

Measured discharge = 18 cfs

Transect number							
1	2	3	4	5	6	7	8

			Discharge				
24.9	17.1	16.1	15.7				

			Stage				
93.2	93.4	94.6	94.8				

			Plotting stage				
0.83	0.78	0.75	0.82				

Stage/discharge relationship (S vs Q) S=A\*Q\*\*B+SZF

A =	0.5966	0.5459	0.2955	0.3381			
B =	0.1027	0.1257	0.3356	0.3221			
SZF =	92.3	92.6	93.9	93.9			

			B coefficient LOG/LOG discharge/stage relationship				
9.73	7.95	2.98	3.11				

=====

Upper Dungeness site

Changes made in cells for calibration

Data file = UDNML58

Changed

Transect	Vertical	From	To
1	8	N=0	1.0
1	10	Vel=0.01	0.1
1	11	Vel=0.01	0.1
1	12	Vel=0.01	0.1
1	24	N=0	1.0
1	25	N=0	1.0
2	10	N=0	1.0
2	26	N=0	1.0
4	6	N=0	0.3
4	26	N=0	0.3

Upper Dungeness site      Velocity adjustment factors  
Data file =      UDNML58  
Measured discharge =      18 cfs

Transect	Flow	VAF
1	18.1	0.991
1	75.3	2.395
2	18.1	1.008
2	75.3	2.632
3	18.1	1.000
3	75.3	1.314
4	18.1	1.000
4	75.3	1.373

Upper Dungeness site

Calibration information for calculated discharges

Data file = UDNHLC58

Measured discharge = 75 cfs

Transect number							
1	2	3	4	5	6	7	8

			Discharge				
93.9	77.3	66.2	67.8				

			Stage				
93.3	93.5	95.2	95.3				

			Plotting stage				
1.39	1.05	1.15	1.3				

Stage/discharge relationship (S vs Q) S=A\*Q\*\*B+SZF

A = 0.8867 0.4785 0.1743 0.2709

B = 0.0990 0.1808 0.4500 0.3721

SZF = 91.9 92.5 94 94

B coefficient LOG/LOG discharge/stage relationship

10.1 5.53 2.22 2.69

=====

Upper Dungeness site

Changes made in cells for calibration

Data file = UDNHLC58

Changed

Transect	Vertical	From	To
1	31	N=0.00	0.40

Upper Dungeness site      Velocity adjustment factors  
 Data file =      UDNHLC58  
 Measured discharge =      75 cfs

Transect	Flow	VAF
1	16.6	0.273
1	30.0	0.453
1	75.3	0.998
1	150.0	1.817
2	16.6	0.465
2	30.0	0.623
2	75.3	1.000
2	150.0	1.437
3	16.6	0.952
3	30.0	0.961
3	75.3	1.000
3	150.0	1.011
4	16.6	0.766
4	30.0	0.860
4	75.3	1.000
4	150.0	1.114

Upper Dungeness site      Calibration information for calculated discharges

Data file =                    UDNMCH78

Measured discharge =        3 cfs

Transect number							
1	2	3	4	5	6	7	8

2.1	3.3	Discharge
-----	-----	-----------

94.9	95.4	Stage
------	------	-------

0.3	0.6	Plotting stage
-----	-----	----------------

Stage/discharge relationship (S vs Q)     $S=A*Q^{**}B+SZF$

A =        0.2844    0.3059

B =        0.0701    0.5660

SZF =      94.6      94.8

B coefficient LOG/LOG discharge/stage relationship  
14.26      1.77

=====

Upper Dungeness site      Changes made in cells for calibration

Data file =                    UDNMCH78

Transect	Vertical	From	To	Changed
----------	----------	------	----	---------

--no changes required--

Upper Dungeness site      Velocity adjustment factors  
Data file =      UDNMCH78  
Measured discharge =      3 cfs

Transect	Flow	VAF
1	0.8	0.448
1	1.0	0.519
1	2.7	0.998
1	5.1	1.494
2	0.8	5.194
2	1.0	3.163
2	2.7	1.002
2	5.1	0.707

Lower Dungeness site

## Calibration information for calculated discharges

Data file = LDUNL  
 Measured discharge = 35.5 cfs

Transect number								
1	2	3	4	5	6	7	8	
Discharge								
32.8	43.5	34.3	54.3	47.3	36.8	32.7	64.9	
Stage								
195.8	196.1	196.4	196.5	197.1	197.1	198.2	198.6	
Plotting stage								
0.85	0.65	0.97	1.11	1.66	1.7	1.14	1.5	
Stage/discharge relationship (S vs Q)						$S=A*Q^{**}B+SZF$		
A =	0.2640	0.1156	0.3067	0.2310	0.6795	0.7236	0.4258	0.5271
B =	0.3350	0.4577	0.3258	0.3930	0.2316	0.2369	0.2825	0.2506
SZF =	194.9	195.4	195.4	195.4	195.4	197.1	197.1	
B coefficient LOG/LOG discharge/stage relationship								
2.99	2.19	3.07	2.55	4.32	4.22	3.54	3.99	

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Lower Dungeness site

## Changes made in cells for calibration

Data file = LDUNL

Transect	Vertical	From	To	Changed
5	22	N=0.822	3.00	
5	33	N=0.308	2.00	
7	7	N=0.072	2.00	
7	17	N=0.286	0.50	

Lower Dungeness site      Velocity adjustment factors  
 Data file =      LDUNL  
 Measured discharge =      35.5 cfs

Transect	Flow	VAF
1	35.5	0.994
1	351.5	2.151
2	35.5	0.995
2	351.5	1.258
3	35.5	0.998
3	351.5	2.322
4	35.5	1.000
4	351.5	1.354
5	35.5	0.982
5	351.5	4.964
6	35.5	0.997
6	351.5	3.607
7	35.5	0.999
7	351.5	2.455
8	35.5	0.995
8	351.5	2.483

Lower Dungeness site

## Calibration information for calculated discharges

Data file = LDUNNM  
 Measured discharge = 351.5 cfs

		Transect number						
1	2	3	4	5	6	7	8	
Discharge								
349.6	395.8	333	384.9	344.8	306.3	358.1	338.2	
Stage								
196.8	197.1	197.5	197.7	198	198.3	199.3	199.4	
Plotting stage								
1.88	1.69	2.07	2.31	2.64	2.9	2.23	2.29	
Stage/discharge relationship (S vs Q) S=A*Q**B+SZF								
A =	0.2463	0.1580	0.2896	0.3704	0.8012	0.7019	0.4045	0.7675
B =	0.3470	0.3962	0.3386	0.3075	0.2041	0.2478	0.2903	0.1877
SZF =	194.9	195.4	195.4	195.4	195.4	195.4	197.1	197.1
B coefficient LOG/LOG discharge/stage relationship								
2.88	2.52	2.95	3.25	4.9	4.03	3.45	5.33	

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Lower Dungeness site

## Changes made in cells for calibration

Data file = LDUNNM

Transect	Vertical	Changed	
		From	To
5	11	N=0.072	0.50
8	27	N=0.054	1.00
8	31	N=0.054	3.00

Lower Dungeness site      Velocity adjustment factors  
 Data file =      LDUNM  
 Measured discharge =      351.5 cfs

Transect	Flow	VAF
1	35.5	0.690
1	351.5	1.000
2	35.5	0.648
2	351.5	1.000
3	35.5	0.496
3	351.5	1.000
4	35.5	0.315
4	351.5	1.000
5	35.5	0.158
5	351.5	1.000
6	35.5	0.418
6	351.5	1.000
7	35.5	0.564
7	351.5	1.000
8	35.5	0.287
8	351.5	0.998

Lower Dungeness site

## Calibration information for calculated discharges

Data file = LDUNMH  
 Measured discharge = 351.5 cfs

		Transect number					
1	2	3	4	5	6	7	8
349.6	395.8	Discharge 333	384.9	344.8	306.3	358.1	338.2
196.8	197.1	Stage 197.5	197.7	198	198.3	199.3	199.4
1.88	1.69	Plotting stage 2.07	2.31	2.64	2.9	2.23	2.29
A =	0.3831	0.0530	0.3567	0.0003	0.1703	0.1068	0.2939
B =	0.2716	0.5789	0.3028	1.5297	0.4691	0.5767	0.3446
SZF =	194.9	195.4	195.4	195.4	195.4	197.1	197.1
Stage/discharge relationship (S vs Q) S=A*Q**B+SZF							
B coefficient LOG/LOG discharge/stage relationship							
3.68	1.73	3.3	0.65	2.13	1.73	2.9	0.97

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Lower Dungeness site

## Changes made in cells for calibration

Data file = LDUNMH

Transect	Vertical	Changed	
		From	To
5	11	N=0.072	0.50
8	27	N=0.054	1.00
8	31	N=0.054	4.00

Lower Dungeness site      Velocity adjustment factors  
 Data file =                  LDUNMH  
 Measured discharge =        351.5 cfs

Transect	Flow	VAF
1	351.5	1.001
1	441.0	1.139
2	351.5	1.000
2	441.0	0.975
3	351.5	1.001
3	441.0	1.097
4	351.5	1.000
4	441.0	0.948
5	351.5	1.000
5	441.0	1.136
6	351.5	0.999
6	441.0	0.858
7	351.5	1.000
7	441.0	1.026
8	351.5	0.996
8	441.0	0.665

Lower Dungeness site

Calibration information for calculated discharges

Data file = LDUNHIGH

Measured discharge = 441 cfs

		Transect number						
1	2	3	4	5	6	7	8	
		Discharge						
482.6	482.7	375.4	380.5	452.9	428.2	441.8	465.7	
		Stage						
97	97.3	97.6	97.8	98.4	98.8	99.5	100.2	
		Plotting stage						
2.05	1.9	2.22	2.41	3	3.4	2.4	3.19	
		Stage/discharge relationship (S vs Q)					S=A*Q**B+SZF	
A =	0.3416	0.1941	0.0040	0.1003	0.1373	0.0257	0.3392	0.3692
B =	0.2900	0.3692	1.0649	0.5350	0.5043	0.8061	0.3212	0.3510
SZF =	94.9	95.4	95.4	95.4	95.4	95.4	97.1	97.1
		B coefficient LOG(LOG discharge/stage relationship						
	3.45	2.71	0.94	1.87	1.98	1.24	3.11	2.85

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Lower Dungeness site

Changes made in cells for calibration

Data file = LDUNHIGH

Transect	Vertical	Changed	
		From	To
8	6	N=0	2.0
8	42	N=0	5.0

**Lower Dungeness site**      **Velocity adjustment factors**  
**Data file =**                  LDUNHIGH  
**Measured discharge =**        441 cfs

<b>Transect</b>	<b>Flow</b>	<b>VAF</b>
1	351.5	0.891
1	441.0	1.000
2	351.5	0.924
2	441.0	1.000
3	351.5	1.086
3	441.0	1.000
4	351.5	0.884
4	441.0	1.000
5	351.5	0.891
5	441.0	0.999
6	351.5	1.303
6	441.0	0.998
7	351.5	0.960
7	441.0	1.000
8	351.5	1.001
8	441.0	0.997

Table 5. Combined WUA for steelhead spawning in the upper site, RM 4.2.  
WUA = weighted useable area (sq ft) per 1000 ft of stream.

Discharge (cfs)	Modelled channel					Total WUA
	Main	Right T 1	Right T 3-6	Left T 5-8	Middle T 7,8	
10	1993.76					1993.76
20	4448.03					4448.03
30	6996.07					6996.07
40	9644.39					9644.39
50	12288.81					12288.81
60	14720.05					14720.05
70	17021.71					17021.71
80	19072.71					19072.71
90	20808.60					20808.60
100	22148.86					22148.86
110	23141.94					23141.94
120	23890.83					23890.83
130	24446.02					24446.02
140	24717.44					24717.44
150	24780.63					24780.63
160	24649.89					24649.89
170	24425.98					24425.98
180	24129.38					24129.38
190	25070.00					25070.00
200	25071.00					25071.00
220	24934.00					24934.00
240	24534.00			112	3	24649.00
260	27345.17			224	140	27709.17
280	26694.89	39		920	477	28130.89
300	25927.36	469		1350	1109	28855.36
330	24705.81	1071	60	2266	1738	29840.81
350	25450.19	1675	133	2750		30008.19
375	23793.45	3008	573	3700		31074.45
400	22330.92	3668	900	4175		31073.92
425	20984.47	4275	1600	5020		31879.47
450	19660.96	5093	1921	5540		32214.96
475	18424.31	5335	2584	6371		32714.31
500	18506.00	5659	2876	7175		34216.00
525	17494.00	5775	3168	7400		33837.00
550	16515.00	5916	3735	8000		34166.00
575	15612.00	5922	4258	8325		34117.00
600	15669.29	5949	4462	8700		34780.29
625	14787.34	6003	4832	8950		34572.34
650	14039.52	5991	4999	9300		34329.52
675	13329.78	5955	5288	9450		34022.78
700	12682.59	5879	5413	9618		33592.59
725	12072.16	5847	5603	9700		33222.16
750	11514.29	5816	5669	9821		32820.29

Table 5. Combined WUA for steelhead juvenile in the upper site, RM 4.2.  
 WUA = weighted useable area (sq ft) per 1000 ft of stream.

Discharge (cfs)	Modelled channel					Total WUA
	Main	Right T 1	Right T 3-6	Left T 5-8	Middle T 7,8	
10	221.69					221.69
20	461.22					461.22
30	707.45					707.45
40	942.85					942.85
50	1245.66					1245.66
60	1553.06					1553.06
70	1864.15					1864.15
80	2135.72					2135.72
90	2384.16					2384.16
100	2567.39					2567.39
110	2630.85					2630.85
120	2649.80					2649.80
130	2658.30					2658.30
140	2648.06					2648.06
150	2586.42					2586.42
160	2519.48					2519.48
170	2412.93					2412.93
180	2284.58					2284.58
190	2029.00					2029.00
200	1914.00					1914.00
220	1751.33					1751.33
240	1678.80			26	18	1722.80
260	1613.61	5		47	35	1700.61
280	1577.17	30		113	52	1772.17
300	1527.25	65		145	88	1825.25
330	1452.19	141	10	207	134	1944.19
350	2086.80	186	21	240		2533.80
375	1968.97	268	50	275		2561.97
400	1875.39	297	66	301		2539.39
425	1796.32	404	82	335		2617.32
450	1712.83	487	118	365		2682.83
475	1642.13	518	155	389		2704.13
500	1518.00	560	172	415		2665.00
525	1444.00	601	192	437		2674.00
550	1385.00	625	228	462		2700.00
575	1247.53	627	264	476		2614.53
600	1216.74	637	280	490		2623.74
625	1187.98	648	313	500		2648.98
650	1152.68	667	328	509		2656.68
675	1115.10	671	347	511		2644.10
700	1086.07	665	354	513		2618.07
725	1056.29	646	366	514		2582.29
750	1021.55	641	369	515		2546.55

Table 5. Combined WUA for steelhead adult in the upper site, RM 4.2.  
 WUA = weighted useable area (sq ft) per 1000 ft of stream.

Discharge (cfs)	Modelled channel					Total WUA
	Main	Right T 1	Right T 3-6	Left T 5-8	Middle T 7,8	
10	12.01					12.01
20	88.58					88.58
30	235.80					235.80
40	513.42					513.42
50	638.38					638.38
60	630.53					630.53
70	722.48					722.48
80	770.45					770.45
90	740.00					740.00
100	711.00					711.00
110	612.00					612.00
120	610.24					610.24
130	590.28					590.28
140	550.55					550.55
150	523.88					523.88
160	513.07					513.07
170	467.87					467.87
180	439.95					439.95
190	448.00					448.00
200	452.00					452.00
220	468.00					468.00
240	468.74					468.74
260	432.67					432.67
280	394.7					394.70
300	386.44					386.44
330	325.96			1		326.96
350	473.95			1		474.95
375	489.31			6		495.31
400	453.02			8		461.02
425	369.91	5		8		382.91
450	339.85	19		6		364.85
475	323.85	37		5		365.85
500	268.73	48		2		318.73
525	262.78	55		2		319.78
550	267.71	63	1	1		332.71
575	265.99	74	5	1		345.99
600	260.19	79	13	1		353.19
625	251.47	77	25	1		354.47
650	246.25	74	37	1		358.25
675	234.76	76	47	1		358.76
700	245.91	79	51	1		376.91
725	255.59	79	54	2		390.59
750	288.74	76	52	2		418.74

Table 5. Combined WUA for dolly varden juvenile in the upper site, RM 4.2.  
WUA = weighted useable area (sq ft) per 1000 ft of stream.

Discharge (cfs)	Modelled channel					Total WUA
	Main	Right T 1	Right T 3-6	Left T 5-8	Middle T 7,8	
10	579.84					579.84
20	1350.76					1350.76
30	2133.61					2133.61
40	2851.32					2851.32
50	3436.59					3436.59
60	3969.57					3969.57
70	4458.00					4458.00
80	4620.00					4620.00
90	4902.00					4902.00
100	5147.00					5147.00
110	5341.00					5341.00
120	5467.00					5467.00
130	5528.00					5528.00
140	5551.00					5551.00
150	5555.00					5555.00
160	5556.00					5556.00
170	5533.00					5533.00
180	5487.00					5487.00
190	5437.00					5437.00
200	5340.00					5340.00
220	5169.20					5169.20
240	5015.03			21		5036.03
260	4947.68	7		42		4996.68
280	4905.90	30		134		5069.90
300	4856.93	86		191		5133.93
330	4706.20	228	8	304		5246.20
350	5501.88	333	18	360		6212.88
375	5172.21	515	49	468		6204.21
400	4804.96	693	121	527		6145.96
425	4500.87	996	162	633		6291.87
450	4258.73	1289	252	680		6479.73
475	4091.10	1473	340	770	1	6675.10
500	3928.51	1774	390	844	2	6938.51
525	3784.20	2059	437	902	3	7185.20
550	3657.63	2203	533	965	6	7364.63
575	3535.26	2379	620	1025	8	7567.26
600	3400.93	2549	661	1070	10	7690.93
625	3244.03	2696	740	1105	13	7798.03
650	3094.11	2809	781	1132	13	7829.11
675	2945.33	2836	862	1156	17	7816.33
700	2828.15	2858	898	1169	20	7774.15
725	2702.86	2866	972	1189	23	7752.86
750	2625.30	2892	1007	1200	26	7750.30

Table 5. Combined WUA for coho spawning in the upper site, RM 4.2.  
 WUA = weighted useable area (sq ft) per 1000 ft of stream.

Discharge (cfs)	Modelled channel					Total WUA
	Main	Right T 1	Right T 3-6	Left T 5-8	Middle T 7,8	
10	3247.74					3247.74
20	6527.33					6527.33
30	9364.73					9364.73
40	11638.93					11638.93
50	11204.00					11204.00
60	12271.00					12271.00
70	12754.00					12754.00
80	13124.00					13124.00
90	13340.00					13340.00
100	13408.00					13408.00
110	13409.00					13409.00
120	13329.00					13329.00
130	13180.00					13180.00
140	13130.00					13130.00
150	13157.00					13157.00
160	13105.00					13105.00
170	12985.00					12985.00
180	12848.00					12848.00
190	12375.58					12375.58
200	12300.25					12300.25
220	11730.87					11730.87
240	11324.76			322	2	11648.76
260	11008.36	45		689	3	11745.36
280	10430.63	172		1299	4	11905.63
300	9822.65	480		1713	14	12029.65
330	9145.65	1266	172	2530	16	13129.65
350	10082.60	1922	354	2933	19	15310.60
375	9254.77	2600	750	3600	21	16225.77
400	8674.18	2835	1451	3953	23	16936.18
425	8382.99	3440	1860	4350	25	18057.99
450	8026.43	3569	2565	4510	32	18702.43
475	7780.15	4063	2950	4671	38	19502.15
500	7561.00	3953	3447	4800	50	19811.00
525	7471.00	4007	3800	4948	58	20284.00
550	7360.00	3976	4135	4875	75	20421.00
575	7187.00	3855	4449	4867	91	20449.00
600	7155.58	3693	4548	4805	98	20299.58
625	6913.21	3584	4440	4771	114	19822.21
650	6799.86	3342	4246	4726	130	19243.86
675	6721.75	3185	4082	4688	142	18818.75
700	6597.31	3243	4091	4620	161	18712.31
725	6403.72	3295	4101	4440	175	18414.72
750	6196.27	3323	4099	4275	199	18092.27

Table 5. Combined WUA for coho juvenile in the upper site, RM 4.2.  
WUA = weighted useable area (sq ft) per 1000 ft of stream.

Discharge (cfs)	Modelled channel					Total WUA
	Main	Right T 1	Right T 3-6	Left T 5-8	Middle T 7,8	
10	7902.34					7902.34
20	8815.83					8815.83
30	8973.38					8973.38
40	8882.49					8882.49
50	8733.99					8733.99
60	8535.33					8535.33
70	8269.22					8269.22
80	7997.99					7997.99
90	7729.19					7729.19
100	7469.30					7469.30
110	7230.72					7230.72
120	7023.35					7023.35
130	6845.96					6845.96
140	6693.32					6693.32
150	6544.15					6544.15
160	6390.32					6390.32
170	6256.42					6256.42
180	6140.08					6140.08
190	4965.90					4965.90
200	4878.40					4878.40
220	4737.50			203		4940.50
240	3491.83			3350	440	7281.83
260	3362.3	868		5785	468	10483.30
280	3255.9	2305		6585	501	12646.90
300	3173.5	3330		6820	572	13895.50
330	3098.77	3505	2096	7116	698	16513.77
350	3556.08	3563	4193	7178	824	19314.08
375	3415.72	3550	4583	7160	893	19601.72
400	3291.91	3359	4780	7106	1051	19587.91
425	3148.79	3175	4788	7010	1155	19276.79
450	3005.91	3039	4746	6920	1327	19037.91
475	2890.29	2540	4692	6826	1465	18413.29
500	2930.00	2919	4632	6694	1486	18661.00
525	2828.00	2897	4576	6564	1820	18685.00
550	2724.00	2878	4533	6397	2075	18607.00
575	2814.28	2842	4531	6290	2475	18952.28
600	2735.48	2775	4536	6120	2520	18686.48
625	2676.36	2706	4543	6000	2804	18729.36
650	2624.29	2655	4542	5790	3025	18636.29
675	2574.08	2626	4530	5660	3137	18527.08
700	2530.20	2614	4534	5508	3354	18540.20
725	2481.26	2635	4537	5320	3400	18373.26
750	2453.76	2663	4538	5170	3589	18413.76

Table 5. Combined WUA for chinook spawning in the upper site, RM 4.2.  
WUA = weighted useable area (sq ft) per 1000 ft of stream.

Discharge (cfs)	Modelled channel					Total WUA
	Main	Right T 1	Right T 3-6	Left T 5-8	Middle T 7,8	
10	321.74					321.74
20	1581.30					1581.30
30	3540.72					3540.72
40	5873.34					5873.34
50	8417.51					8417.51
60	10680.56					10680.56
70	12731.23					12731.23
80	14605.27					14605.27
90	16177.73					16177.73
100	17503.44					17503.44
110	18449.64					18449.64
120	19130.85					19130.85
130	19676.76					19676.76
140	19996.37					19996.37
150	20114.57					20114.57
160	21237.71					21237.71
170	22043.38					22043.38
180	22683.38					22683.38
190	23192.16					23192.16
200	23535.65					23535.65
220	23732.13					23732.13
240	23517.93			2		23519.93
260	23169.59			19		23188.59
280	22620.5	6		78		22704.50
300	21840.72	300		290		22430.72
330	20156.12	962		830		21948.12
350	19986.84	1470		1203		22659.84
375	18228.82	2210	19	1924		22381.82
400	16236.19	2690	85	2520		21531.19
425	14754.78	3369	180	3280		21583.78
450	13623.07	3986	569	3725		21903.07
475	12652.66	4340	1053	4332		22377.66
500	13057.00	4801	1489	4875		24222.00
525	12384.00	5191	1909	5258		24742.00
550	11749.00	5316	2349	5610		25024.00
575	11897.44	5346	2805	6050		26098.44
600	11233.88	5353	3010	6325		25921.88
625	10439.17	5354	3400	6477		25670.17
650	9712.14	5278	3610	6670		25270.14
675	9077.71	5223	4007	6820		25127.71
700	8540.96	5131	4340	6943		24954.96
725	7980.67	5037	4462	6990		24469.67
750	7476.20	5013	4600	7023		24112.20

Table 5. Combined WUA for chinook juvenile in the upper site, RM 4.2.  
WUA = weighted useable area (sq ft) per 1000 ft of stream.

Discharge (cfs)	Modelled channel					Total WUA
	Main	Right T 1	Right T 3-6	Left T 5-8	Middle T 7,8	
10	510.54					510.54
20	1069.43					1069.43
30	1704.69					1704.69
40	2265.80					2265.80
50	2437.13					2437.13
60	2277.23					2277.23
70	2254.69					2254.69
80	2183.27					2183.27
90	2096.79					2096.79
100	1922.89					1922.89
110	1714.27					1714.27
120	1621.99					1621.99
130	1644.16					1644.16
140	1635.30					1635.30
150	1590.82					1590.82
160	1521.00					1521.00
170	1431.29					1431.29
180	1335.07					1335.07
190	1204.00					1204.00
200	1178.00					1178.00
220	1191.00					1191.00
240	1094.94			73		1240.94
260	1063.25	15		115		1308.25
280	1003.87	62		208		1481.87
300	972.19	139		231		1573.19
330	885.43	314	26	280		1785.43
350	1195.53	361	58	320	1	2254.53
375	1210.97	415	100	390	1	2505.97
400	1216.21	432	158	430	1	2666.21
425	1184.03	454	200	490	2	2818.03
450	1185.05	541	268	533	3	3060.05
475	1205.66	545	336	561	4	3208.66
500	1061.00	484	355	554	10	3008.00
525	1031.00	459	375	541	10	2947.00
550	986.00	424	406	532	17	2880.00
575	972.00	384	410	531	17	2828.00
600	956.00	335	388	528	28	2735.00
625	946.00	360	378	529	36	2742.00
650	888.39	401	386	508	38	2691.39
675	870.25	421	398	475	46	2639.25
700	868.03	439	408	447	54	2609.03
725	913.50	461	414	447	60	2682.50
750	959.17	497	405	440	65	2741.17

Table 5. Combined WUA for chinook adult in the upper site, RM 4.2.  
WUA = weighted useable area (sq ft) per 1000 ft of stream.

Discharge (cfs)	Modelled channel					Total WUA
	Main	Right T 1	Right T 3-6	Left T 5-8	Middle T 7,8	
10	407.35					407.35
20	501.37					501.37
30	573.33					573.33
40	636.20					636.20
50	691.92					691.92
60	741.53					741.53
70	787.12					787.12
80	829.69					829.69
90	867.00					867.00
100	900.68					900.68
110	931.91					931.91
120	959.39					959.39
130	982.67					982.67
140	1001.79					1001.79
150	1016.27					1016.27
160	1027.08					1027.08
170	1035.16					1035.16
180	1039.47					1039.47
190	1041.17					1041.17
200	1040.72					1040.72
220	1058.36				1	1059.36
240	1065.6			43	2	1110.60
260	1055.05	8		77	2	1142.05
280	1032.33	26		112	2	1172.33
300	1006.53	56		130	3	1195.53
330	962.19	79	27	160	3	1231.19
350	1001.36	92	56	175	3	1327.36
375	967.80	111	71	192	4	1345.80
400	933.84	123	85	220	5	1366.84
425	898.85	138	96	225	6	1363.85
450	861.63	152	106	240	7	1366.63
475	826.16	161	112	255	9	1363.16
500	827.00	173	122	266	14	1402.00
525	791.00	185	129	275	14	1394.00
550	756.00	197	138	288	18	1397.00
575	740.42	203	143	296	22	1404.42
600	712.54	213	150	303	23	1401.54
625	687.97	221	158	309	26	1401.97
650	664.85	230	162	318	28	1402.85
675	645.07	236	169	322	32	1404.07
700	624.30	242	172	327	35	1400.30
725	604.33	248	178	330	36	1396.33
750	585.14	252	182	335	38	1392.14

Table 5. Combined WUA for pink spawning in the upper site, RM 4.2.  
 WUA = weighted useable area (sq ft) per 1000 ft of stream.

Discharge (cfs)	Modelled channel					Total WUA
	Main	Right T 1	Right T 3-6	Left T 5-8	Middle T 7,8	
10	2881.55					2881.55
20	7382.52					7382.52
30	11259.00					11259.00
40	14104.86					14104.86
50	16889.08					16889.08
60	19042.66					19042.66
70	20660.06					20660.06
80	21546.25					21546.25
90	22056.96					22056.96
100	22366.33					22366.33
110	22436.32					22436.32
120	22303.07					22303.07
130	21985.71					21985.71
140	22006.58					22006.58
150	22699.37					22699.37
160	22692.54					22692.54
170	22606.43					22606.43
180	22535.92					22535.92
190	22647.46					22647.46
200	22425.60					22425.60
220	22346.38					22346.38
240	22062.67			524		22586.67
260	21177.41	320		1048		22545.41
280	20283.33	970		2777		24030.33
300	19334.54	1672		3781		24787.54
330	17964.26	2680	122	5492		26258.26
350	18508.50	3076	244	6198		28026.50
375	17358.17	3560	975	7400		29293.17
400	16416.76	4361	1533	8007		30317.76
425	15497.98	4959	2250	9000		31706.98
450	14626.47	5319	2999	9600	9	32553.47
475	13868.07	5480	3750	10279	18	33395.07
500	13872.00	5492	4370	10700	100	34534.00
525	13320.00	5556	5150	11059	120	35205.00
550	12714.00	5627	5368	11440	393	35542.00
575	12429.39	5657	5842	11625	410	35963.39
600	11813.38	5713	6066	11670	517	35779.38
625	11291.43	5678	6600	11737	633	35939.43
650	10881.07	5576	6790	11775	657	35679.07
675	10477.42	5492	7026	11740	682	35417.42
700	10093.10	5350	7027	11674	717	34861.10
725	9834.43	5222	7039	11550	775	34420.43
750	9539.70	5087	7045	11441	925	34037.70

Table 6. WUA for anadromous salmonids in the lower site, RM 2.3. WUA = weighted useable area (sq ft) per 1000 ft of stream.

Discharge (cfs)	Steelhead			Dolly varden			Coho			Chinook			Pink	
	Spawning	Juvenile	Adult	Juvenile	Spawning	Juvenile	Juvenile	Spawning	Juvenile	Adult	Spawning	Spawning		
10	1673.19	222.56	10.72	417.78	3144.62	6891.17	84.64	663.96	630.29	2364.93				
20	4562.62	482.23	42.55	1130.07	6823.93	8447.83	1070.78	1096.93	763.06	7547.35				
30	7144.93	752.77	119.58	1827.60	9777.75	9104.50	2918.90	1299.79	861.60	11720.41				
40	10114.49	1049.42	274.64	2492.53	12357.56	9182.38	5777.25	1368.12	946.08	15337.25				
50	13261.93	1347.22	520.12	3145.23	14931.62	9066.83	8842.02	1533.32	1021.50	18591.57				
60	16165.44	1611.36	875.09	3742.59	17195.30	8908.16	11582.72	1780.47	1090.21	21215.02				
70	18932.50	1874.23	1125.49	4265.42	18852.52	8660.97	14260.29	1934.85	1151.86	23417.50				
80	21723.09	2145.14	1175.72	4775.07	20165.21	8309.63	16961.45	2356.00	1208.95	25544.46				
90	24373.76	2418.77	1108.29	5271.72	21429.82	7961.68	19277.21	2280.00	1262.09	27215.36				
100	26699.02	2687.60	1061.06	5761.97	21946.73	7631.36	21381.45	2200.00	1311.05	28840.02				
120	30497.52	3170.09	1252.19	6706.32	22494.54	6980.11	25064.89	2067.00	1399.17	30541.12				
140	32996.61	3546.36	1672.79	7512.23	22101.19	6431.34	27796.18	1829.00	1476.23	31250.63				
160	34498.76	3799.63	833.56	8163.55	20186.11	5874.69	29775.96	1786.38	1543.37	31133.06				
180	35259.26	3888.57	737.14	8651.42	18613.88	5397.74	31004.45	1702.25	1604.05	30227.08				
200	35442.89	3853.58	647.50	8868.05	17603.40	5012.69	31393.33	1621.51	1653.26	28901.44				
220	35060.64	3700.33	609.80	8973.37	16679.54	4682.13	31211.61	1561.43	1683.75	27313.11				
240	34357.25	3483.53	596.90	8902.05	15717.98	4401.24	30343.05	1472.15	1711.52	25626.81				
260	33313.32	3217.72	638.96	8661.93	14842.15	4200.32	29094.21	1421.03	1726.76	23970.42				
280	32175.55	2921.41	683.51	8334.82	13981.63	4035.79	27674.11	1429.63	1734.64	22658.35				
300	30994.35	2686.43	685.68	7882.27	13290.34	3939.19	25913.66	1457.67	1736.63	21630.30				
320	29818.96	2507.13	605.73	7383.75	12694.86	3901.69	24003.99	1478.61	1727.35	20461.51				
330	27684.71	2341.11	594.51	6743.95	11786.68	3524.48	21490.85	1470.97	1636.97	19017.75				
340	27773.96	2330.10	627.14	6691.64	11776.65	3518.83	21477.24	1514.01	1661.72	18951.87				
350	27825.83	2313.44	650.86	6645.41	11809.91	3540.33	21455.45	1578.21	1686.17	18973.95				
360	27875.70	2300.41	638.79	6616.97	11866.68	3567.49	21434.97	1616.30	1708.55	19263.24				
370	27928.29	2318.03	643.67	6589.98	11980.99	3605.87	21395.45	1650.23	1733.77	19396.51				
380	27965.68	2346.85	662.35	6006.00	12150.65	3657.27	21344.74	1680.34	1758.37	19851.90				
390	28000.24	2385.58	741.00	5967.00	12314.70	3721.15	21259.52	1726.94	1783.20	20641.89				
400	26109.00	2951.00	784.00	5943.00	11533.00	3780.57	19243.00	1860.00	1679.00	19115.00				
410	25998.00	2623.00	826.00	5149.57	11623.00	3838.60	19044.00	1920.00	1545.72	17080.85				
420	25919.00	2660.00	868.32	5086.65	11812.00	3919.08	18921.00	1967.00	1540.43	16862.44				
430	23020.02	2779.79	896.80	5035.89	10490.38	4044.76	16042.81	2046.74	1533.26	16876.60				
440	22677.22	2804.52	924.38	4991.34	10483.76	4209.74	15716.26	2074.10	1526.31	16922.90				
450	22377.63	2834.69	938.29	4952.21	10483.94	4381.60	15402.69	2102.02	1522.71	16875.28				
460	22096.45	2853.41	957.67	4937.44	10537.34	4584.38	15143.33	2129.98	1523.28	16843.93				
470	21904.27	2868.24	973.75	4934.59	10621.96	4774.08	14976.01	2153.35	1525.76	16909.55				
480	21768.73	2887.22	974.77	4936.92	10767.25	4979.77	14862.46	2166.17	1529.23	17129.22				
490	21642.09	2910.71	972.15	4950.92	10897.78	5166.67	14809.65	2174.30	1532.98	17232.20				
500	21557.50	2929.94	966.34	4976.70	11143.96	5331.29	14783.76	2181.21	1538.96	17404.25				

**APPENDIX A. Diversion Measurements**